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ECOLOGICAL STUDIES OF COLONIAL SEABIRDS AT CAPE THOMPSON AND CAPE LISBURNE, ALASKA

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A. Objectives

The objective of this study is to provide current information on the ecology of seabirds nesting at Cape Thompson and at Cape Lisburne. The data obtained at Cape Thompson will be compared to recent historical studies in an attempt to describe "redevelopment" changes which may have occurred. Investigations at Cape Lisburne will further increase our understanding of seabird biology in the Chukchi Sea. By broadening the ecological data base, effects of resource development in this region may be more accurately measured.

B. Conclusions

1. Approximately equal numbers of murres occupy the cliffs at Cape Thompson and Cape Lisburne.

2. *The number of murres which were counted at Cape Thompson in 1976 and 1977 were essentially the same and were significantly* lower *than number reported for the early 1960's. The cause of the decrease in not understood.*

3. *Results of food habit studies indicate that major differences exist between the* trophic *positions of Common and Thick-billed* Murres. *The results also suggest that annual and seasonal variations occur in the food base of* murres *at Cape Thompson and Cape* Lisburne.

4. *The foraging radii of murres may be large and may change yearly and/or seasonally.* Murres, *however, also appear to exhibit a tendency to heavily utilize an area to the south and southwest of Cape Thompson and an area to the northeast and north of Cape Lisburne.*

5. *Food habit studies of kittiwakes reflect yearly and seasonal variability in prey. Variations in kittiwake productivity between years and between colonies might be related to the food differences.*

6. Because *food availability changes between years and because particular prey appear to be more important in one season than in another, we can not list specific single critical* links *in the food chain of* murres *or* kittiwakes. *Prey which are probably of major importance, 'on the average', however, are cod,* sculpin, *Sand* Launce *and shrimp.*

7. *Populations of other seabird species inhabiting the Cape Thompson colonies appear to be essentially the same now as in 1960.*

C. Implications with respect to OCS oil and gas development

The colonies at Cape Thompson and Cape Lisburne support most of the breeding seabirds in the eastern Chukchi *Sea. The birds constitute a major component of the ecosystem in this region. Perturbations of the environment by resource development in the Hope Basin could threaten the health and stability of these seabird populations.*

The birds nesting at Cape Thompson, Cape Lisburne and Cape Lewis could be threatened by OCS development in several ways. Murres concentrate in leads in the sea ice during spring and early summer. Breeding activities begin long before the ice has broken up or gone out from shore and the only open water available to the birds is in leads. If these leads were contaminated by spilled oil, large numbers of birds would be affected.

Currents originating south of the Bering Strait could bring spilled oil through feeding areas and into nearshore regions at Cape Thompson, Cape Lisburne and Cape Lewis. Spills south or west of Cape Thompson, Cape Lisburne and Cape Lewis would be driven closer to these colonies or onto their beaches by prevaling southerly and westerly winds. High velocity northerly winds, also prevalent in the area, could, on the other hand, prevent oil from reaching the colonies themselves if all conditions were right. Because of the currents and wind patterns in the region, however, floating oil will almost certainly impinge upon foraging areas whether or not it actually reaches the coastline.

At Cape Thompson floating oil originating from spills in the northern Bering Strait or southern Chukchi Sea may offer the greatest potential danger to the colony. At Cape Lisburne floating oil originating offshore of the Cape Thompson-Point Hope vicinity or originating some distance northward of Cape Lisburne may offer the greatest potential danger to this colony, since it may enter the large clockwise gyre north and east of the colony where foraging birds are generally present.

The Cape Thompson colonies also are located at a point potentially attractive for use during exploration activities, and more importantly, for the construction of a major marine terminal. The construction of a terminal facility could be harmful to the seabird populations nesting there. Increased human activity could cause a variety of disturbances that may adversely influence the reproductive success of several species.

11. INTRODUCTION

A. General nature and scope of study

The sea cliffs at Cape Thompson and Cape Lisburne *provide nesting habitat for nine species of seabirds, three species of raptors and ravens. The colonies at these sites contain the largest concentrations of murres and kittiwakes in the eastern* Chukchi *Sea and are the northernmost colonies in western North America.*

Prior to the present study the only formal investigation of seabirds nesting in this region was made at Cape Thompson during Project Chariot between 1959 and 1961. Information obtained by Swartz *(1966; 1967)* during *the early 1960's at Cape Thompson has provided a sound base upon which we can build in an attempt to bridge gaps in our knowledge of seabird ecology within this region of Alaska.*

B. Specific Objectives

The specific objectives of this study are to:

1. Determine the numbers of cliff-nesting seabirds breeding at the Cape Thompson and Cape Lisburne colonies;

2. Determine the phenology of breeding activities and reproductive success of these birds;

3. Obtain data on food habits and foraging areas of the principal species in these colonies;

4. Expand the ecological data base of the Cape Thompson and Cape Lisburne region.

C. Relevance to problems *of* petroleum development

The Hope Basin *is subject to lease* sales *to allow oil and gas exploration and development. Within this part of the* Chukchi Sea exist areas critical to the success of several species of seabirds. The birds are not randomly distributed throughout the region but are concentrated at breeding colonies and feeding areas. This clumped distribution makes them particularly susceptible to oil pollution and to habitat alteration.

The weather and climate, oceanography, topography and geology of the Lisburne Peninsula were studied specifically by Allen and Weedfall (1966), Kachadoorian (1966), Campbell (1966), Flemming and Heggarty (1966) and Creager and McManus (1966) during 1959-1961. Several aspects of these studies, as they related to the region's seabirds, were discussed briefly by Swartz (1966; 1967). Swartz (1966) also briefly described sea ice cover near the Cape Thompson seabird colonies.

Certain information presented by the investigators listed above has been extracted, summarized and freely incorporated here with certain of our 1976-1977 observati"ons. Particular emphasis is placed on those environmental aspects that strongly influence the Cape Thompson-Cape Lisburne seabird habitat, and which would play major roles in the various interactions which could occur between this habitat and eventual Outer

Continental Shelf oil and gas exploration and development in the Chukchi Sea.

Sea ice is an important aspect of the Cape Thompson-Cape Lisburne seabird habitat. By February open water is greatly restricted throughout the region. The Bering Sea current flowing northward through the Chukchi Sea and the region's winter air mass circulation and high velocity surface winds, however, combine to assure that some open water is present all winter. A large persistant but dynamic lead system extends from the Bering Strait northeastward toward Cape Thompson where it then swings northward past Point Hope (Shapiro pers. comm; Barry et al 1977). A review of 1975-1977 ERTS satelite imagery also reveals the presence of two persistent, large open polynya; one extends south and west of Cape Lisburne and another lies somewhat farther offshore opposite Cape Thompson (Barry et al 1977).

Sea ice generally begins to break up in the region by about mid-June and is well broken up by late June. In the Cape Thompson area, shorefast ice generally persists the longest where it adheres to either side of the Point Hope spit. Shorefast ice also persists in the embayment between Point Hope and Kivalina and this ice zone is often several kilometers wide.

In the Cape Lisburne area, shorefast ice similarly persists along the north-facing coast, east of Alokut Point.

Wind and ocean currents influence the movement of the broken decomposing ice. In the Cape Thompson area, southerly and westerly winds and ocean currents cause the wide band of broken ice to be retained along the shoreline south of Point Hope well through the second week, and often the third week of July. In 1959-1961 this ice was well broken up "and going" by 7 July (Swartz pers. comm.). In 1976, ice in the embayment was well broken up and dissipating by 20 July and was last observed on 29 July. In 1977 the ice was well broken *Up by about* 10-12 July and was gone by 22 July.

In the Cape Lisburne area, northerly winds and a large current eddy cause a several kilometer-wide band of broken ice to be retained along the north coast well through the third week of July. In 1977 the ice was well broken up by 19 July and the last ice was observed on 25 July.

Open, icefree water generally exists well through October in the Cape Thompson area. By the last week in October ice is generally present again north of Cape Lisburne, and during November ice cover begins to build in the Cape Thompson area.

Recent OCSEAP studies have produced evidence that winter-spilled oil may lie "dormant" underneath sea ice. While trapped under the ice, petroleum undergoes less weathering and retains its toxicity longer than it does when exposed to the atmosphere and to sunlight. Such oil also migrates upward through the ice and can become entrapped for long periods of time (Beaufort Sea Synthesis Meeting, Pt. Barrow, 7-11 February 1977). In addition to becoming a unique long-term source of chronic pollution, oil which has been trapped in or under the ice could appear in leads near rookeries or in critical feeding areas. Leads are important to murres and to other seabirds because they represent the only open water available for courtship and for winter and spring feeding. Oil filled leads and ice

edges coated with oil would reduce the extent of already limited habitat and would present a direct danger to birds concentrated there.

The eastern Chukchi Sea is dominated by a strong northward, predominantly barotropic current flow entering it through Bering Strait. Current speeds in the summer are higher than in the winter and the currents closely parallel the isobaths. Assuming an average speed of 0.5 knots, water passing through Bering Strait would reach the latitude of Point Hope in about 15 days.

Currents, after passing Cape Prince of Wales, tend to turn eastward. Water flow tends to enter Kotzebue Sound along the southern entrance and leave it along the northern edge near Cape Krusenstern. Offshore in the large embayment betweenthe Seward Peninsula and the Point Hope-Cape Thompson region, currents appear more diffuse but the trend in flow is northeast toward the Kivalina-Cape Thompson coast. The northeastward surface current flow was illustrated in 1976 and 1977 by floating walrus carcasses. These carcasses, which undoubtedly originated from hunting activities in the Little Diomede Island-Cape Prince of Wales-Shishmaref region, were deposited on beaches between Cape Krusenstern and Point' Hope. Maximum concentration appeared to occur from about Kivalina to Point Hope.

An important discontinuity between offshore and coastal waters exists. This becomes most striking in the Cape Thompson-Point Hope vicinity. Slowly moving nearshore waters flow predominantly northwestward and parallel to the Kivalina-Cape Thompson coast. Offshore waters flowing generally parallel to the coast but at faster speeds and in a more northerly direction converge toward Point Hope. This discontinuity between coastal and offshore waters is evident in late June - mid July from the Cape Thompson cliff tops when ice floes are present. A small, weak back-eddy effect also is often present close to shore between Point Hope and the Kismilok Mountain vicinity, particularly when a north or northwesterly wind is blowing.

Currents flowing past points and islands are modified. Current flow accelerates toward Point Hope in the Cape Thompson area. North of Point Hope current flow slows and a large clockwise eddy is created downstream of this spit. Farther north, the current accelerates past Cape Lisburne. A somewhat stronger, larger gyre effect appears to be present north of this prominent coastal feature. This large clock-wise eddie is created by the prominent westward projection of the Lisburne Peninsula. A smaller, more localized clock-wise eddy is created by Cape Lisburne itself. Both the large-scale and the smaller more local eddy effects are evident during breakup when ice floes are present. North and easterly winds enhance these clock--wise flows. Near the cliffs water and ice are carried around the Cape to the south.

A weak gyre effect also may occur *offshore of the* Shishmaref-*Cape Espenburg area, a result of eddying currents created by* Bering *Strait water flowing past Cape Prince of* Wales.

The airmass circulation and the winds of the Cape Thompson region tend to be stronger in the winter than in the summer. Variability increases in the summer months and monthly parameters in one year may not correspond to values obtained in other years.

In general, the Cape Thompson-Cape Lisburne region experiences more wind than most other parts of Alaska. The wind tends to blow more

frequently from a northerly direction except during the period May-August when southerly winds occur slightly more often. North winds generally persist longer than south winds and have a higher velocity. During the summers of 1976 and 1977 the general pattern of variable strong on-shore winds and storms, interspersed by occasional but often violent high velocity northern winds blowing offshore was the rule.

Southerly winds and storm cells moving northward through Bering Strait create longshore and onshore swells. If southerly winds associated with a storm cell persist for a day or two after sea ice is gone, surf commonly builds to over one, and often over two meters in height along all westerly-facing coastline. Southerly storms associated with rough seas and high surf may occasionally persist for up to a week, but generally do not persist as long as the northerly winds. During southerly storms, the Cape Thompson cliffs and the Cape Lisburne cliffs south of Alokut Point are exposed to the full force of these winds and the accompanying waves which may break several meters up them. This condition (southerly, changing to westerly winds as storms move up through the Chukchi Sea) is prevalent enough to 'build' and terrace the beaches once the ice dissipates in mid to late July.

The high velocity northerly surface winds, characteristic of the region, are influenced by the terrain. The Lisburne and Kemegrak hills channel these strong winds over the full length of the Cape Thompson cliffs and over the Cape Lisburne cliffs which lie south of Alokut Point, while the portion of the Cape Lisburne colony situated to the east of the Cape is exposed to their full force. These northerly winds commonly (1976-1977) reach speeds of 40-50 knots, and at Cape Thompson in 1976, an aircraft indicated about 75 knot gusts during one storm. Wind speeds are generally greater near the cliff-tops. Velocities of downdrafts created by the presence of the high seacliffs may easily reach or even exceed 100 knots. During moderate to strong southerly winds, a similar effect is created on the north side of the Cape Lisburne cliffs. During such winds the Cape Lisburne Air Force Base runway is closed to landing and departing aircraft. The violence of downdrafts and extreme turbulence is believed. to be responsible for fatally flipping a large military transport aircraft into the sea near Cape Lisburne shortly after take off several years ago. We have observed murres, approaching the cliffs at altitudes of at least 50 meters, driven almost straight down into the sea, and during more moderate conditions, stall out when entering what must be bubbles of very low pressure. Swirling water spouts and plumes of water up to an estimated 30 meters high were common occurrences at the base of the cliffs and for up to one kilometer offshore. This phenomenon also occurs, though less spectacularly, along the Telavirak Hills, a few kilometers downcoast from Ogotoruk Creek.

Prudhoe Bay bound barge traffic passes through the foraging zones of seabirds nesting at Cape Thompson and Cape Lisburne. Future barge and tanker traffic will likely follow similar shipping lanes. During spring and early summer ice breaker type tanker traffic will probably follow the major Bering Stait-Chukchi Sea-Point Barrow lead system (see Barry et al. 1977).

Fuel from chronic leaks and bilge waste will become more common in the Chukchi Sea as marine transportation increases. Major oil spills, originating in the northern Bering Sea or the southeastern Chukchi Sea could be transported into the vicinities of the Cape Thompson, Cape Lisburne and Cape Lewis seabird colonies by ocean currents and wind.

Spills well to the south of Cape Thompson would be carried northward through the Bering Strait and northeasterly toward the Point Hope area by the prevailing current pattern. Oil would flow through foraging areas as it was carried towards Cape Thompson by those currents. Strong southwesterly winds, characteristic of the ice-free summer and fall months, could easily drive oil ashore between Cape Krusenstern and Point Hope.

Residues of distant spills or oil from spills originating nearer the latitude of Cape Thompson could be carried far to the north past Cape Lisburne and toward feeding grounds of this colony. Southwesterly and westerly winds also could drive oil ashore between Point Hope and Cape Lisburne.

Oil carried northward in the current flow, could become entrapped in the slower more complex currents lying off of the entrance to Kotzebue Sound; in the weak back-eddy south of Point Hope along the Cape Thompson colonies; in the stronger eddy lying north of the Point Hope spit; or in the large clockwise gyre located northeast of Cape Lisburne. Oil slowed or entrapped in the complex currents west and north of Kotzebue Sound would be circulated through a large area believed to be important foraging grounds of seabirds nesting at Cape Thompson. Similarly, oil carried into the large gyre north of Cape Lisburne would be circulated through an area which appears to include the major foraging grounds of the seabirds nesting at Cape Lisburne. These patterns of current flow would tend to prolong the presence of oil in areas essential to these large seabird colonies. Both feeding seabirds and food-web organisms, therefore, would be exposed to the direct effects of oil for a longer period of time.

If oil were driven ashore along the Cape Thompson coastline or along the coastline east of Cape Lisburne it could not only pose a problem by becoming engrained in the beach sediments, but also could contaminate the lagoon systems. Once in these lagoons, the 'building' nature of the beaches would inhibit the return of oil into the open sea and would result in long term pollution. The lagoons are important to seabirds, especially to Black-legged Kittiwakes and Glaucous Gulls as well as to waterfowl and shorebirds.

The severe storms which occur frequently during the ice-free months would make containment and cleanup operations difficult, if not impossible in the Cape Thompson-Cape Lisburne region. During these storms aircraft are often unable to land at either site and the combination of high winds and rough seas make the success of boat-based operations very doubtful.

Shore-based operations associated with OCS oil and gas exploration and development in the Hope Basin also are potential sources of conflict between people and the seabirds nesting in the Cape Thompson-Cape Lisburne vicinities. The Project Chariot site at the mouth of Ogotoruk Creek is only about 1.6 kilometers downcoast from the first of the five Cape Thompson seabird colonies. The site has been proposed as a possible marine terminal location (M. Halebsky, Global Marine Development Inc., pers. comm.). The deeper nearshore waters off of Ogotoruk Creek made this location an attractive choice. The still existent but abandoned airstrips just north of the creek mouth would be convenient for some exploration activities.

Large permanent facilities constructed so close to the Cape Thompson nesting cliffs could have adverse effects on seabird populations. Various forms of direct disturbance to the birds which nest on the relatively unstable cliffs may be of greatest concern. Any activities that could

persistantly flush birds from the cliffs should be avoided. Although few data, particularly quantified data, concerning the effects of many forms of disturbance exist, we would recommend that aircraft approach and departure patterns be carefully regulated. Besides the possibility of egg loss and interruption of normal nesting behavior, large aircraft and helicopters operating near to these colonies could increase the amount of rock-fall, an important source of natural mortality at these colonies.

Tanker terminals or gathering facilities immediately adjacent to the Cape Thompson colonies could increase the likelihood of oil spills and could be sources of smaller but chronic petroleum pollution. Causeways and above surface structures could conflict with the foraging flocks returning to the cliffs particularly on foggy days. Murres fly to and from the colonies at speeds of about 50 mph (Swartz 1967), however, they exhibit poor maneuverability and require relatively large turning radii. Collisions on foggy days when flights are concentrated along the beach lines are possible.

Air traffic to and from a terminal site could increase the disturbance near the colony. At Cape Lisburne we have an excellent opportunity to study that possibility. Air traffic at the Air Force Station consists of several small aircraft and at least one larger (C-130, DC-6 or Electra) aircraft per week. Almost all departures and approaches occur in front of the north-facing portion of the seabird colony and many thousands of murres and kittiwakes are usually flushed from the cliffs. The effects on productivity of murres nesting on the north shore are as yet unknown. Chicks are produced by those birds but the production might not be as great as on the west shore where aircraft disturbance is less.

A particularly strong correlation exist between human activity and the accumulation of refuse. Garbage dumps frequently attract scavengers which are generally facultative scavengers-predators, for example gulls, Ravens and foxes. At Cape Lisburne where a sizable garbage dump exists, we have not observed uncommonly high numbers of gulls or Ravens (for example, no more than at Cape Thompson) and have not seen any foxes. Ravens and Arctic Foxes are frequent at the site during the winter but the facility does not appear to act like a magnet *on them during the summer.*

We must stress, however, that many activities associated with OCS oil and gas exploration and development are potential *sources of impact and conflict. Real situations may, in fact, pose new problems or may not pose problems to the degree originally suspected. All activities near seabird colonies, however, should be approached with caution and the effects of possible perturbations should be investigated fully.*

III. CURRENT STATE OF KNOWLEDGE

Nine species of seabirds were found breeding at Cape Thompson in 1959-1961 (Swartz 1966). These were, in order of decreasing numbers, Thick-billed Murres (Uris lomvia), Common Murres (Uris aalge), Black-legged Kittiwakes (Rissa tridactyla), Horned Puffins (Fratercula corniculata), Glaucous Gulls (Larus hyperboreus), Tufted Puffins (Lunda cirrhata), Pelagic Cormorants (Phalacrocorax peligicus), Black Guillemots (Cepphus grylle) and pigeon Guillemots (Cepphus columba). In addition to these species, Golden Eagles (Aquila chrysaetos), Gyrfalcons (Falco rusticolus), Peregrine Falcons (Falco peregrinus) and Ravens (Corvus corax) were found nesting in small numbers on the cliffs.

The majority of the birds are in the immediate vicinity of the sea cliffs from late April through mid-September. Nearly all of the nutrition which supports the colony is obtained from the sea and amounts to an estimated 13,000 metric tons per 130-day breeding season (Swartz 1966).

Swartz (1966) summarized the few references to the colonies which existed prior to his study. Those references and data we obtained at Cape Thompson and Cape Lisburne in 1976 were presented in our first annual report (see Springer and Roseneau 1977).

IV. STUDY AREA

The general locations of the Cape-Thompson and Cape Lisburne seabird rookeries are illustrated in Figure 1. Detailed historical information on the environment of the Cape Thompson-Cape Lisburne regions and the seabird habitat at Cape Thompson can be found in Willimovsky and Wolfe (1966).

The Cape Thompson seabird habitat, originally described in detail by Swartz (1966) was also described briefly by Springer and Roseneau (1977). The Cape Lisburne seabird habitat, located about 88 km north of Cape Thompson, and areas nearby have not been adequately described prior to this report. For comparative purposes, some descriptive information pertaining to the Cape Thompson colonies will be repeated here.

The five distinct seabird colonies that occur at Cape Thompson are illustrated in Figure 2. These colonies comprise about 6.8 km of an approximate 11.4 km section of coastline between the southern end of Crowbill Point and the northern end of Imnakpak cliff. The colonies are separated by creek valleys, beaches and low bluffs varying from a few hundred meters to about 2.4 km in length. The colonies themselves occupy the higher more stable sedimentary cliffs formed by the southern terminus of the Kemegrak Hills.

Heights of the five colonies vary from about 9 meters to 185 meters above sea level. Colony 1 and Colony 4 are the smallest in approximate area and Colony 1 also offers the fewest ledges suitable to seabirds. Colony 2 and Colony 5 are the largest in approxiamte area, and Colony 3, the second highest, is most similar to Colony 5 and has an area approximately between that of colonies 1-4 and colonies 2-5.

While the five major cliffs supporting the five seabird colonies provide the most suitable nesting habitat, some sections of fractured low cliffs and bluffs between the colonies provide nesting habitat for occasional pairs of Glaucous Gulls and larger numbers of Horned Puffins. The most important habitat of this type, designated as Colony O lies

Figure 1. Locations of the Cape Thompson, Cape Lewis and Cape Lisburne seabird colonies.

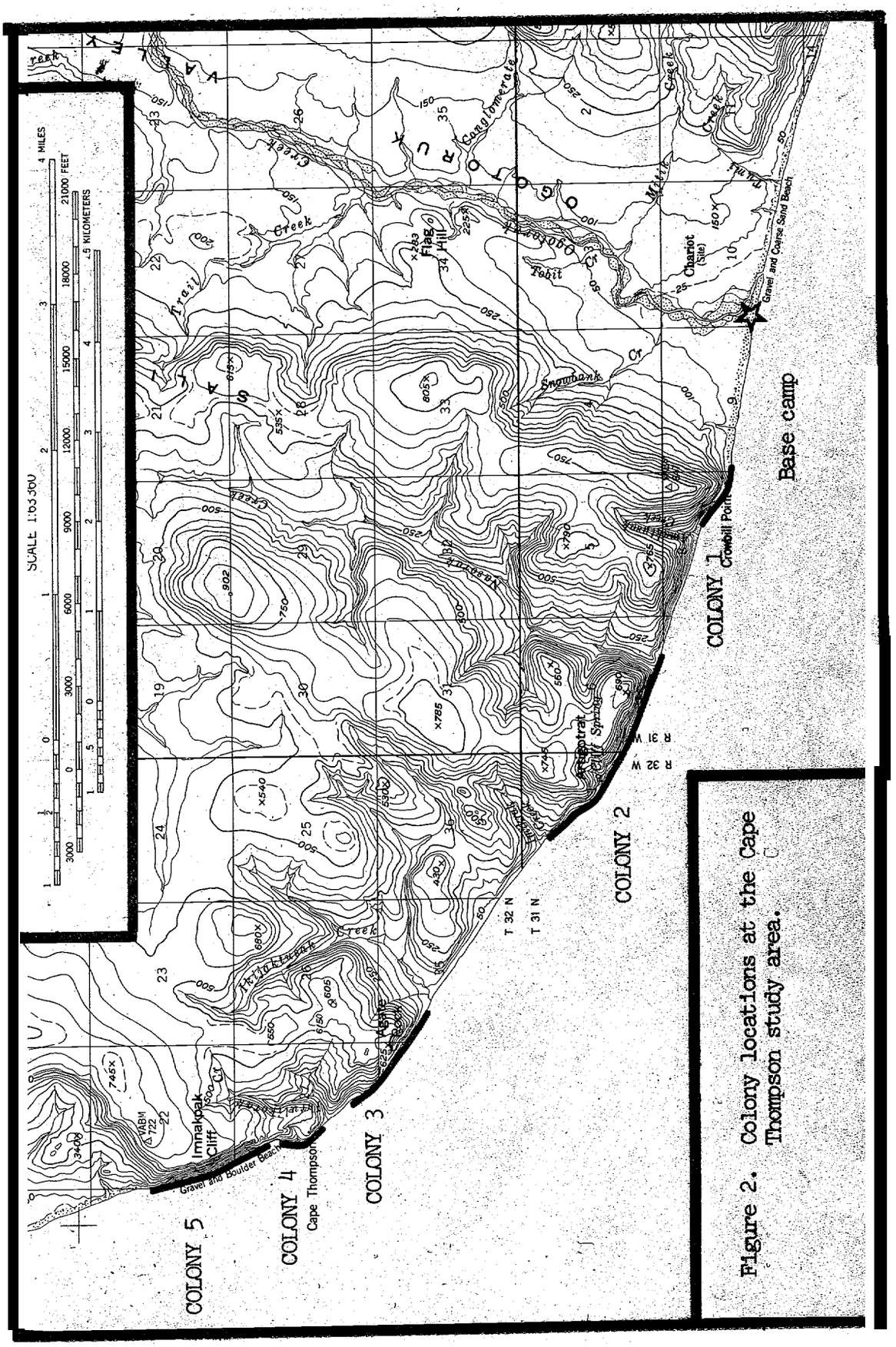


Figure 2. Colony locations at the Cape Thompson study area.

between Colonies 1 and 2.

Barrier beaches and lagoons occur both northwest (upcoast) and southeast (downcoast) of Cape Thompson. The basic physical characteristics of these lagoons and the zooplankton found in them have been described by Johnson (1966). Johnson (1966) discovered that these lagoons were, "... strikingly dissimilar ecologically." While all lagoons undoubtedly receive some utilization by kittiwakes and gulls, Akoviknak and Kemegrak lagoons just upcoast of Colony 5 appear to be the most important to flocks of resting and 'socializing' "flocks of kittiwakes. The small lagoon formed by the natural closure of the Ogotoruk Creek mouth appears to be the preferred habitat for these activities downcoast of the colonies. Isuk, Agarak, Ikijaktusak and Nasorak creeks, though not as large as Ogotoruk Creek, offer additional important habitat to both kittiwakes and gulls. These lagoons and creeks, particularly Ogotoruk Creek, also are important sources of mud for kittiwakes during nest construction.

The seabird colony that occurs at Cape Lisburne is illustrated in Figure 3. This colony occupies a nearly continuous cliff briefly broken by three small creek valleys. The colony occupies approximately 7 km of coastline beginning at a point about 1.6 km west of. the western boundary of the Cape Lisburne Air Force Base runway. From there it extends west around Cape Lisburne, then south to a point about 1 km south of Kay Creek. The cliff is the northern terminus of the higher, sedimentary Lisburne Hills. Height of-the colony varies from about 15 meters to 200 meters above sea level; average height is about 125 meters.

While this major Cape Lisburne cliff series provides the most suitable nesting habitat to the seabirds, some sections of lower, fractured and less solid cliffs and bluffs to the south (downcoast) provide nesting habitat for puffins, occasional guillemots and a few pairs of gulls.

East (upcoast) of Cape Lisburne, the lagoon and barrier beaches at the mouth of Igrarok Creek and Ayugatak Creek, along with the larger Ayugatak lagoon provide important habitat to gulls and to this colony's flocks of resting, socializing and mud-gathering kittiwakes. The mouth of Setin Creek, at the east edge of the Cape Lisburne Air Force Base, may have provided some additional habitat to kittiwakes prior to the establishment of the site. South (downcoast) of Cape Lisburne, lagoons are not a prominent feature of the coastline until the Kukpuk River vicinity is reached. The mouths of Kay Creek and Niak Creek provide some important habitat for large groups of kittiwakes.

The seabird colony that occurs at Cape Lewis, approximately 18.5 km south of Cape Lisburne, is illustrated in Figure 4. This smaller colony occupies a relatively low cliff beginning at Cape Lewis that extends south approximately 1 km. Height of the colony varies from about 5 meters to 75 meters. Seabird utilization of the northern (upcoast) 0.2 km of this habitat is low. This section and cliffs to the north of the Cape itself provide some additional puffin nesting habitat.

Several other small seabird colonies occur along the Chukchi Sea coast between Cape Thompson and Cape Lisburne, and between Cape Lisburne and Thetis Creek. The locations of these colonies are illustrated in Figures 4 and 5. These colonies occupy small headlands that vary between about 5 and 45 meters high.

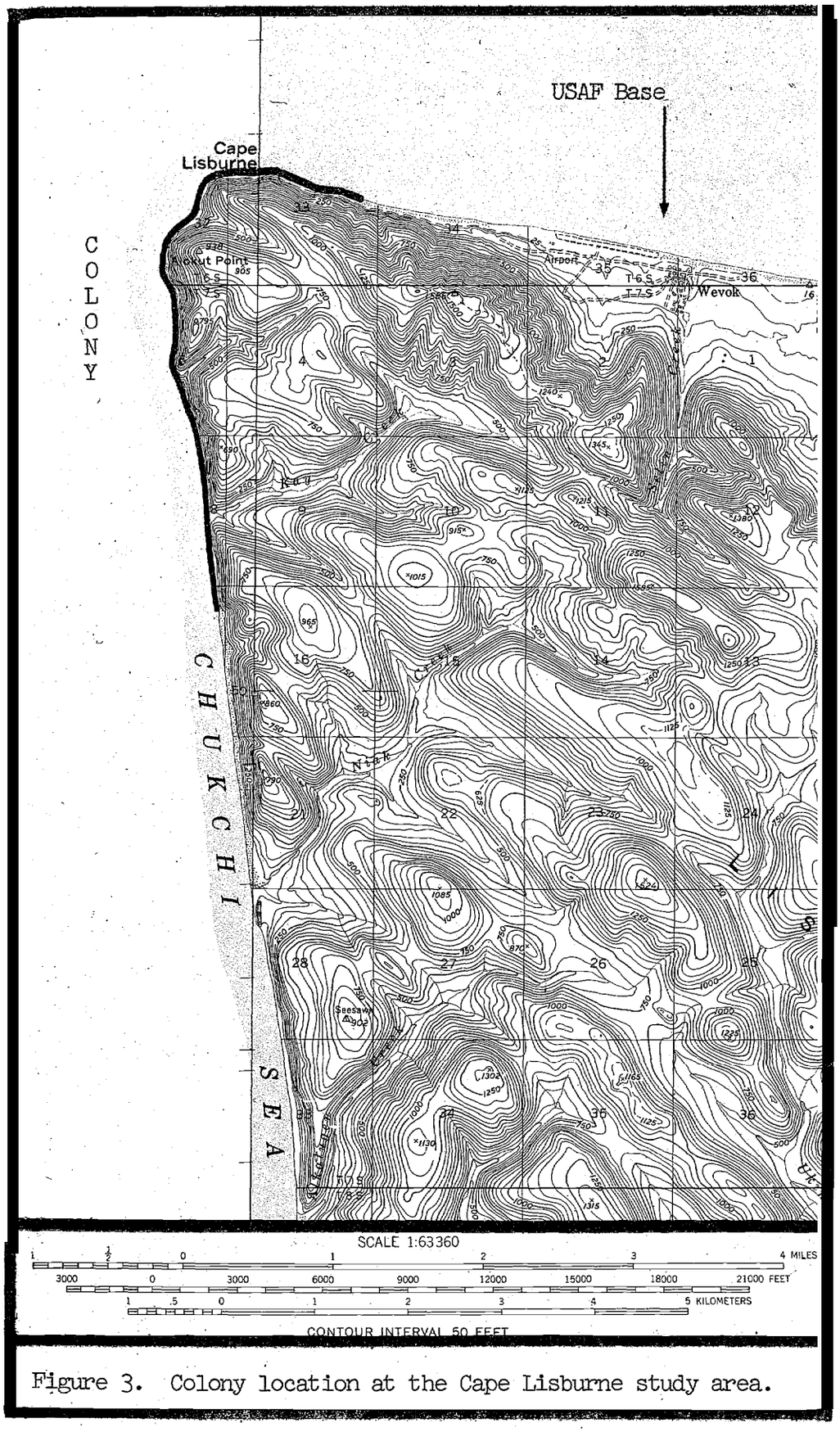


Figure 3. Colony location at the Cape Lisburne study area.

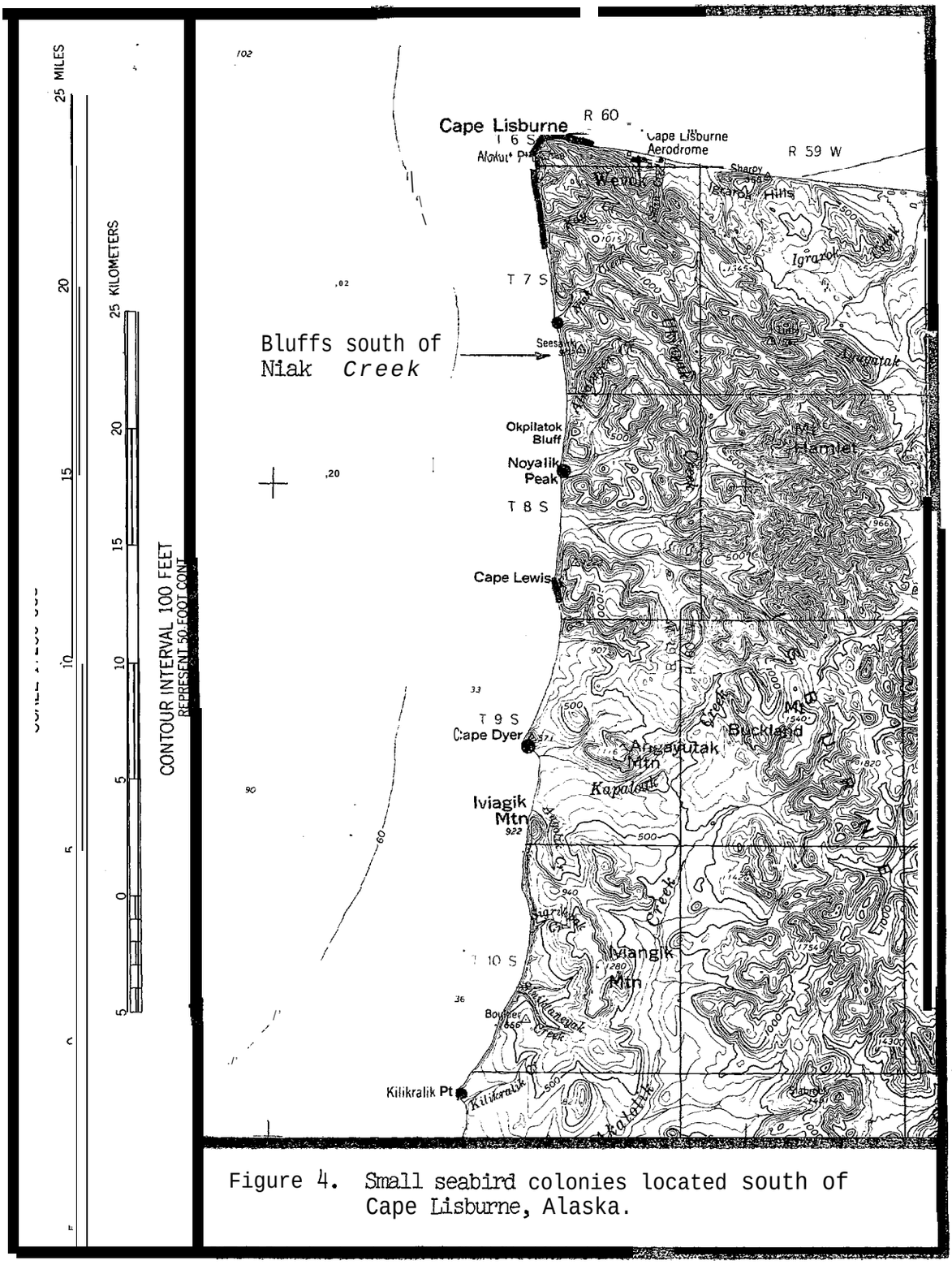


Figure 4. Small seabird colonies located south of Cape Lisburne, Alaska.

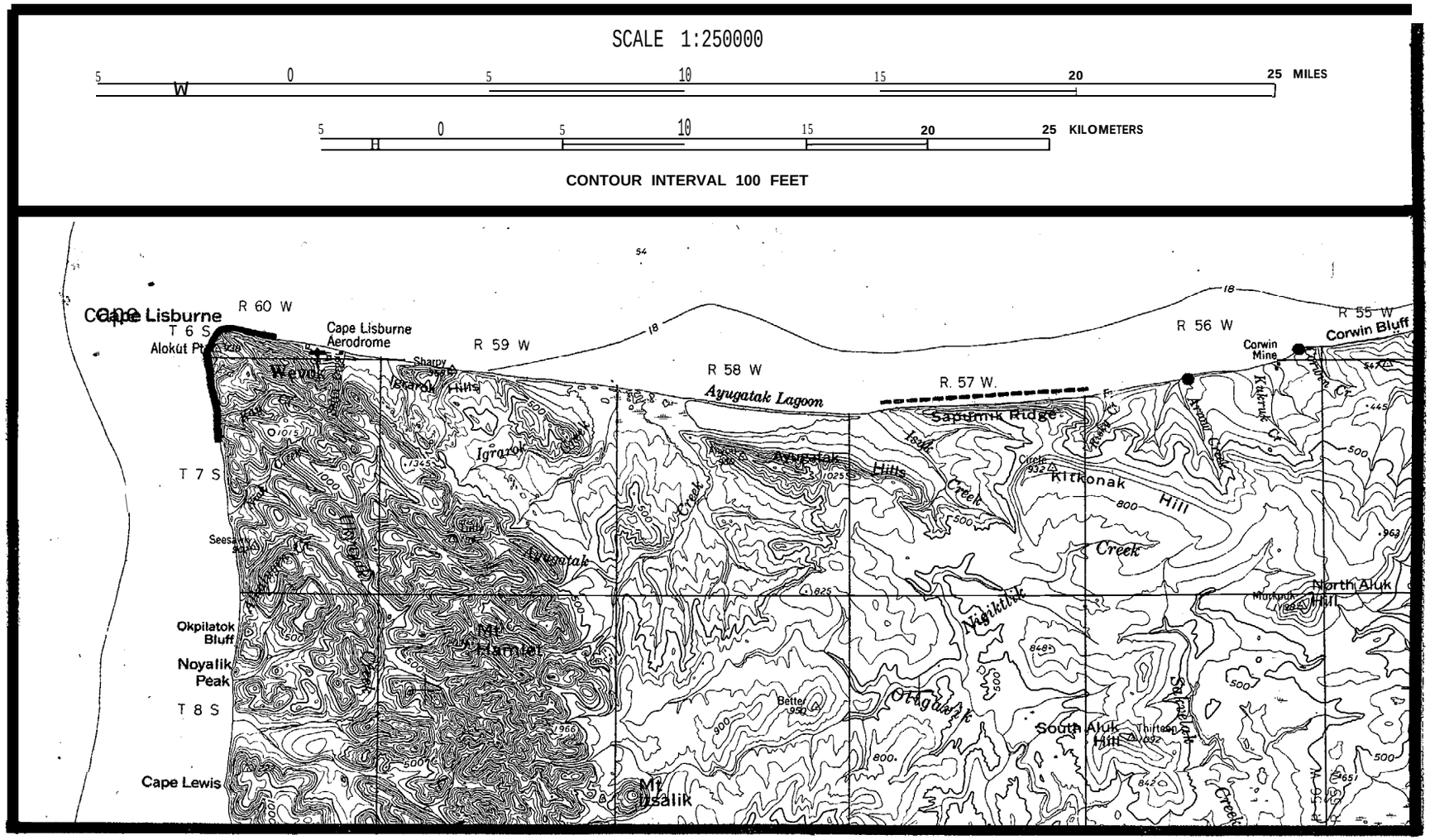


Figure 5. Small seabird concentrations located east of Cape Lisburne, Alaska

Cape Dyer, approximately 25.5 km south of Cape Lisburne, is the largest. Almost all the seabirds occupy a short (0.3 km) section of bluff facing southwest, just south of the tip of the cape. Noyalik Peak is a smaller headland about 14.5 km south of Cape Lisburne. It consists of rock and softer layers of sediments very fractured both horizontally and vertically. A small headland is located about 200 meters south of the mouth of Niak Creek, about 8 km south of Cape Lisburne. Kilikralik Point is a small low headland located about 43 km south of Cape Lisburne and 30 km from Point Hope. Sapumik Ridge begins about 27 km east of Cape Lisburne and consists of a 15 to 45 meter high crumbly bluff that continues for about 8 km farther east. A small rock headland juts out a few meters into the sea about 0.6 km east of the Arrow Creek mouth, about 36 km east of Cape Lisburne. A slightly larger, 10-45 meter high headland, exists just west of the Corwin Creek mouth, about 45 km east of Cape Lisburne.

These headlands and bluffs provide limited habitat to gulls, puffins, cormorants and guillemots. Kittiwakes do not utilize them, nor do murres, with a minor exception at Noyalik Peak where a very few murres, perhaps prospectors, occur.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Field work commenced on 8 June, with a one day visit to Cape Thompson and Cape Lisburne to observe activity about the colonies and to collect specimens. A second collecting trip to Cape Thompson was made on 21 June, however a planned stop at Cape Lisburne on that date and the following day was prevented by adverse weather. Permanent field camps were established at both Cape Thompson and Cape Lisburne on 6 July. Field work terminated at Cape Thompson on 26 August and at Cape Lisburne on 4 September.

A. Census

Swartz (1966) divided the seacliffs at Cape Thompson into five colonies which contained a total of 137 small census plots. The locations of each colony and each plot were recorded on photographs made during the study. We took copies of these photographs into the field in 1976 and in 1977. In 1976 most of the plots established by Swartz were relocated and in 1977 many of the ones which had not been determined with certainty the previous year were found. We now have in hand all 1960 census plot boundaries and in almost all cases we are able to directly compare 1976 and 1977 plot counts with those obtained in 1960 and 1961. Because all of the plots were not located in 1976, certain of the boundaries of plots counted that summer differ from the 1960 boundaries established by Swartz. In 1977 we counted the birds on the plots corresponding to 1976 boundaries and when those differed from 1960 plot boundaries the birds in the 1960 plots were also counted for comparative purposes.

The number of murres in each plot was estimated by groups of ten. These estimates were made by two observers equipped with binoculars and stationed off-shore in a Zodiac raft which was anchored in front of the plot. Colonies 1 and 4 were counted in a single day, however, Colonies 2, 3, and 5 were each counted during multiple days because of the size of the cliffs, the number of birds present and adverse weather and sea conditions. Censusing was timed as much as possible to coincide with the

period of maximum cliff-attendance by the murres, and occurred during the second half of incubation.

Two observers were placed on shore to conduct diurnal activity counts of murres on the days that Colonies 2, 3, and 4 were censused. One or two sections of these colonies were selected for both visibility and bird density and were counted every hour for a 6-7 hour period. Weather conditions and dwindling daylight combined to preclude full 24 hour counts as obtained in 1976. Numbers of birds determined for different plots at different times during the day by the offshore observers were then adjusted for daily activity patterns by dividing the raw score by

$$\frac{\textit{number of birds on compensation plot at time } t}{\max. \textit{number observed on compensation plot}}$$

where t = time a given census plot was counted. Compensation of Colony 5 was done on the basis of the activity patterns determined for Colony 4 and scores for Colony 1 were not compensated.

Black-legged Kittiwakes were counted individually by two observers offshore in the raft on different days from those of the murre counts. No corrections for daily activity patterns were made; however, one 24 hour diurnal activity count was conducted at Colony 4 shortly after most colonies had been censused.

Horned Puffins were also counted individually by two or three observers using methods identical to those employed for kittiwake counts. Counts were timed to coincide with the period of apparent maximum cliff attendance. One 24 hour diurnal activity count was conducted at Colony 4. At colonies where complete counts were' obtained more than once, only the highest score is presented. A count was not obtained at Colony 5.

The population sizes of Tufted Puffins and guillemots were determined by counting individuals during all other censusing activities and by compiling all observations obtained throughout the summer. Glaucous Gulls were counted by locating nests, counting individuals present and by compiling all summer observations.

The population sizes of comorants, Ravens, Golden Eagles and Gyrfalcons were determined by locating nests.

The Cape Lisburne colony was photographed and divided into 75 plots during our reconnaissance in 1976. Copies of these photographs were taken into the field in 1977 and all plots were relocated and censused.

The number of murres in each plot was determined by the same method employed at Cape Thompson. The colony was counted over a six day interval because of the size of the cliffs and the number of birds present. The counts were performed during the second half of the incubation period, and the censusing effort was timed as much as possible to coincide with periods of maximum cliff attendance by the murres.

Two observers were placed onshore to conduct diurnal activity counts of murres each census day. These counts were made at areas of the colony approximately central to the plots being counted on that day. In each area two or three sections of the colony were selected for visibility, bird density and substrate type and were counted every hour for 6–11 hour intervals. Numbers of birds determined on census plots were then adjusted by the method described for Cape Thompson.

Black-legged Kittiwakes were counted directly by one observer from the anchored raft. At 38 of the 75 census plots total birds and total sites

were counted. Total birds only were counted at an additional 19 plots. Observers were unable to count kittiwakes at the remaining 18 census plots, but were able to count sites.

Horned Puffins were counted individually by one observer at the same time kittiwakes were being counted. Counts were completed at 55 of the total 75 census plots. Counts were not obtained at the remaining 20 census plots.

The number of Tufted Puffins, guillemots, gulls, cormorants, raptors and Ravens were determined the same way as at Cape Thompson.

The entire Cape Lewis colony was counted in one day. Fourteen plots were established and photographed. No compensation counts were made; however all other censusing methods were similar to those employed at Cape Thompson and Cape Lisburne.

Counts of birds at other locations were made whenever an opportunity arose. These counts were conducted from the raft, with the exception of Kilikralik Point where numbers were estimated from a Maule fixed-wing aircraft.

B. Phenology of breeding activities

Regular visits were made to the Cape Thompson and Cape Lisburne colonies to determine laying, hatching and fledging dates of all nesting species. Specimens of Common and Thick-billed Murres and of Black-legged Kittiwakes were collected at both of these locales at intervals throughout the summer. Each collected specimen and many of the birds we found dead or injured on the beach were examined for degree of brood patch and gonadal development. Nest checks were made on only one day at Cape Lewis and phonological data were not obtained from any of the other small sites (see Figures 4 and 5) where birds were found nesting.

C. *Food Habits*

Murres and kittiwakes were collected at both Cape Thompson and Cape Lisburne for stomach content analyses. Birds were not collected at Cape Lewis or elsewhere. The majority of the specimens were obtained from flocks that were returning to the colonies from distant feeding areas. Those specimens were collected up to several kilometers away from the cliffs. Other birds were collected as they fed in front of the cliffs, or as they left the colonies to return to foraging areas.

Stomachs from the specimens were removed as soon as possible and the lining of the ventriculus together with the contents were preserved in 70% ethanol. A visual estimate of the percent fullness of each stomach was made and the prey items were identified using standard taxonomic keys and preserved material. Identifications of food items were made by Peter Craig and C. Low of Nanaimo, British Columbia.

VI. RESULT S

A. Murres

Census

A summary of the raw scores and compensated scores for murre censuses made. during each of four years at Cape Thompson are presented in Table 1. The details of the 1977 census at Cape Thompson-are presented in Tables 2-6. We have not included the plot counts for previous years' censuses at Cape Thompson in this report. Those data and the results of the 1977 counts are being computerized so that an analysis of yearly changes can be made more easily.

Table 1. Murre census summary, Cape Thompson.

Raw Scores	Colony 1[1]	2	3	4	5	Total
1960[3]	4186	76,174	26,814	8701	141,544	257,419
1961[3]	5630					
1976	2090	46,722	18,598	6894	79,983	15 4,287
1977	2472	52,828	21,377	7623	59.322	143,621
Compensated Scores						
1960[3]	4186	123,516	43,957	11,723	208,000	391,382
1961[3]	5630	108,598[2]	72,031[2]	8552	210,100[2]	404,011[2]
1976	2090	56,264	26,370	7072	89, 141	180,937[4]
1977	2472	60,610	21,951	8053	61,870	154,956

[1] Colony 1 was not compensated for diurnal activity.

[2] estimate based on partial counts

[3] from Swartz's field notebooks and other unpublished data

[4] compensated for diurnal activity pattern only; figures reported in Springer arid Roseneau (1977) were also compensated for observer handicaps

With the exception of Colony 5, tile raw scores for all colonies are somewhat higher this year than they were in 1976 although the same situation is not true for the compensated scores. The greatest percentage change among any of the colonies occurred in Colony 5 and was large enough to indicate a decline in the overall population. This colony, however, is particularly difficult to count - it is tall with deep recesses which make visibility poor. The raw 1977 totals for Colonies 1 through 4 are uniformly higher than those of 1976. Although the direction of change in the compen-

Table 2. Murre census, Colony 1. Cape *Thompson, 1977.*

		11 August 1977		
		Observer F	*Observer* E	
Plot	Time	Paw	*Paw*	$\bar{x}$
A	2123	0	0	0
B	"	--	--	--
C	2117	330	355	343
D	2108	395	385	390
E	2052	1125	1180	1153
F	2045	0	0	0
G	2038	580	560	570
H	2031	16	16	16
I	2030	0	0	0
Total		2446	2496	2472

Time compensation of Raw $\bar{x}$ is not possible because 24 hr counts were not conducted.

Table 3. Murre census, Colony 2: Cape Thompson, 1977.

Plot	Time	9 August 1977 Observer F Paw	Observer E Paw	$\bar{x}$	Time Comp.
A-1	1510	0	0	9	12
A-2	1512	23	23	23	30
B	1517	130	120	125	165
C	1525	490	535	513	658
D	1535	150	155	153	196
E	1540	1410	1945	1678	2111
F	1608	920	775	848	1005
G	1620	3445	2290	2868	3339
H	1715	2840	2160	2500	2694
I	1735	1860	1635	1748	1882
J	1755	2525	2305	2415	2597
K,L	1818	3220	3100	3160	3442
M	1850	2055	1945	2000	2220
N	1935	1645	1640	1643	1931
O	1940	1910	2015	1963	2320
P	2000	1275	1265	1270	1517
Q	2015	3110	2940	3025	3445
R	2035	710	670	690	752
S	2045	2260	2490	2375	2477
T	2105	2960	3.550	3255	3255
U	2130	2750	2900	2825	3132
V	2150	3395	3300	3348	3995
W	1740	2170	2260	2215	2384
X	1715	1135	1220	1178	1269
Y	1635	3075	3110	3093	3535
Z	1615	1780	1515	1648	1934
AA	1600	685	720	703	850
BB	1540	1000	980	990	1245
CC	1530	1 090	12.35	1163	14'31
DD	1.505	148S	15s0	1518	2071
EE	1455	710	590	650	887
FF	1445	435	445	440	617
GG	1436	370	.350	360	519
HH	1425	285	270	278	401
II	1420	155	160	158	232
Total		53,467	52,172	52,828	60,610

Table 4. Murre census, Colony 3; Cape Thompson, 1977.

Plot	Date	Time	Observer F Raw	Observer E Raw	$\bar{x}$	Time Comp. $\bar{x}$
A	*10 Aug*	*1810*	150	155	153	153
B		*1817*	540	495	518	520
C		*1835*	460	500	480	482
D		*1323*	525	580	553	555
E		1828	545	583	564	567
F		*1841*	605	600	603	608
G	*12* Aug	*2005*	1120	900	1010	1052
H	*10* Aug	1850	580	550	565	571
I	12 Aug	1855	595	950	773	784
J		1745	2570	2665	2618	2621
K	10 Aug	1912	1590	1580	1585	1612
L	12 Aug	1728	1205	1460	1333	1333
M		1705	1435	*1780*	1608	1646
N		1656	6(?0	*670*	635	650
0		1613	1685	*1800*	1743	1909
P		1640	1990	1825	1908	1983
Q	10 Aug	1940	3265	*3200*	3233	3333
R		2013	805	*865*	835	877
S		2020	650	*670*	660	695
Total			20,915	21,904	21,377	21,951

Table 5. Murre census, Colony 4; Cape Thompson, 1977.

		12 August			
Plot	Time	Observer F Raw	Observer F Raw	$\bar{x}$	Time Comp. $\bar{x}$
A	1356	160	155	158	160
B	1358	535	560	548	554
C	1408	990	960	975	985
D	1505	140	130	135	145
E	1420	980	990	985	1015
F	1445	320	300	310	323
G	145s	1075	950	1013	1089
H	1s07	355	338	347	373
I	1515	100	90	95	102
J	1518	580	540	560	604
K	1522	120	130	125	135
L	1528	415	425	420	454
M	1535	480	495	487	526
N	1558	348	300	324	352
O	1530	100	95	98	106
P	1547	690	625	658	713
Q	1539	160	170	165	179
R	1540	220	220	220	238
Total		7768	7473	76'23	8053

Table 6. Murre census, Colony 5; Cape Thompson, 1977.

Plot[1]	Date	Time	Observer F	Observer E	$\bar{x}$	Time Comp.
A	17 Aug	1705	850	1055	953	963
B		1645	2480	2465	2473	2549
C		1612	3040	2790	2915	3101
D		1510	6680	6670	6675	7177
E		1602	2440	2520	2480	2696
F		1420	5910	5970	5940	6253
G	14 Aug	1807	7640	7820	7730	7730
H		1630	8800	9470	9135	9516
I		1420	9070	8775	8923	9199
J		1310	6910	7700	7305	7378
K	13 Aug	1915	2920	3190	3055	3149
L		1840	1765	1710	1738	1755
Total			58,505	60,135	59,322	61,466

[1]Plots are the same as those used in 1976.

sated scores between 1977 and 1976 was variable, the total for 1977 was somewhat higher than 1976 (see Table 7). We believe these data suggest that there has been no appreciable change in the size of the murre population at Cape Thompson between 1976 and 1977. The 1977 census results also support our conclusion from last year that there are substantially fewer murres at Cape Thompson now than in the early 1960's.

Table 7. Score totals, Colonies 1 through 4.

	1960	1961	1976	1977
Raw	115,875		74,304	84,299
Compensated	183,382	194,811	91,796	93,086

The results of our compensation counts at Cape Thompson are presented in Table 8. Because counts were made only during the times that the colony was being censused and not for complete 24-hour cycles, the times designated as 100% may not coincide with the actual peak of maximum attendance. Therefore the compensation factors may be somewhat low.

A rather quick census of the murres at Cape Lisburne was made in 1976. The numbers of birds on many of the larger plots were estimated by hundreds and no compensation counts were made during any of the days of the census. Table 9 presents the results of the 1976 counts. In 1977, all plots were estimated by tens, a method which we hoped would increase the overall accuracy and the precision between observers. The results of our 1977 census are presented in Table 10. Although somewhat more effort was expended in making the 1977 counts, a difference of only 1.5% was obtained between the totals of the raw mean scores for the two years. The raw scores from both years and the compensated scores from 1977 suggest that the size of the murre population at Cape Lisburne is about the same as at Cape Thompson (see Table 11 for compensation factors).

Estimates of the relative numbers of Thick-billed Murres and Common Murres at Cape Lisburne were not made. It is our impression, however, that Thick-billed Murres clearly predominated there as *they did at Cape Thompson.*

Activity patterns

One 24-hour compensation count was made at Cape Thompson in 1977. The activity pattern described by this count is very similar to patterns observed during counts at Cape Thompson in 1976, as shown by Figure 6. These data show peak attendance to occur during the mid-morning hours with a low occurring during the afternoon and another high at about 2000 hours. The bimodal shape of these activity patterns about the colonies are in contrast to the observed patterns of activity to and from the feeding areas, the peaks of which occur about 1990 to 2000 hours. We are not prepared as yet to explain the significance of this difference.

The murres at Cape Lisburne exhibited highly regular daily activity behavior throughout most of the summer. Figure 7 shows the syn-

Table 8. Compensation counts of murres; Cape Thompson, 1977 - per cents of maximum.[1]

Time	9 Aug Colony 2	10 Aug Colony 3	12 Aug Colony 4
1400			99
1430		69	
1500	73		95
1530		79	
1600	83		86
1630		96	
1700	93		96
1730		100	
1800			100
1830		100	
1900	87		98
1930		98	
2000	84		94
2030		94	
2100	100		
2200	80		
2300	67		

[1]Maxima

Colony 2 - 415

Colony 3 - 625

Colony 4 - 359

Table 9. Murre census; Cape Lisburne, 1976.

Plot	Date	Time	Observer B	Observer C	x
1	25 Aug	1825	3500	2600	3050
2			900	700	800
3			4s0	3s0	400
4			150	1s0	150
5		1855	250	250	250
6			1300	1500	1400
7			1200	1000	1100
8			600	600	600
9		1920	2000	1400	1700
10			700	700	700
11			900	600	750
12		2000	1200	1400	1300
13			1000	1100	1050
14			1150	1200	1175
15			4300	4200	4250
16			1800	1700	1750
17		2045	5500	5450	5475
18			2300	2000	2150
19			2800	2500	2650
20			3600	3200	3400
21			2800	1800	2300
22			2100	1300	1700
23		2155	1600	1000	1300
24			1000	1100	1050
25			1050	600	825
26			550	650	600
27	26 Aug		1250	1150	1200
28			1000	1400	1200
29			1500	1800	1650
30			3900	4600	4250
31			3000	3400	3200
32			1900	2500	2200
33			2400	2950	2675
34			5900	3800	4850
35			2400	2050	2225
36			2500	2550	2525
37			550	450	500
38			650	450	550
39			950	900	925
40			2600	2850	2725
41			1000	1200	1100
42			900	700	800
43			1050	1050	1050
44			750	1100	925
45			1200	1350	1275
46			1300	1400	1350
47			900	1250	1075

Plot	Date	Time	Observer B	Observer C	$\bar{x}$
48			550	850	700
49			700	950	825
50			3500	3800	3650
51			1900	2500	2200
52			800	1150	975
53			700	1250	975
54	27 Aug		1s00	900	1200
55			1100	1100	1100
56	28 Aug		2500	2800	2650
57			2600	2700	2650
58			3700	2900	3300
59			3500	4200	3850
60			1000	1200	1100
61			3200	3300	3250
62			3500	4000	3750
63			4600	3600	4100
64			2300	2400	2350
65			1200	1350	1275
66			1000	1500	1250
67			1000	1400	1200
68			1500	2400	1950
69			550	900	725
70			600	1200	900
71			600	1800	1200
72			600	900	750
73			800	1100	950
74			550	700	625
Total:			128,350	130,800	129,575

Table 10. Murre census; Cape Lisburne, 1977.

Plot	Date	Time	Observer C	Observer E	$\bar{x}$	Time Comp.
1	26 July	2100	5250	6410	5830	7571
2		2130	1470	1470	1470	1793
3		2145	520	485	503	592
4		2150	200	200	200	230
5		2045	300	300	300	400
6		2015	1955	1785	1870	2597
7		2005	1150	1380	1265	1782
8		2000	780	840	810	1141
9		1940	920	900	910	1282
10		1930	850	930	890	1271
11		1905	910	945	928	1345
12		1850	1460	1630	1545	2414
13		1825	940	880	910	1596
14		1815	1390	1390	1390	2623
15		1735	3870	3620	3745	7968
16		1705	1100	1140	1120	2383
17		1634	2260	2405	2333	5690
18		1605	1230	1040	1135	3338
19		1600	1945	2015	1980	5824
20	25 July	2245	2620	2610	2615	2696
21		2130	2610	2615	2613	2871
22		2100	3200	3355	3278	3998
23		2045	1202	1105	1154	1443
24		2040	825	845	835	1043
25		2020	1050	1120	1085	1391
26		1950	1115	1335	1225	1612
27		1940	1170	1135	1153	1537
28		1920	1260	1490	1375	1858
29		1900	1720	2005	1863	2552
30		1830	3925	3245	3585	5121
31		1735	3480	4110	3795	6325
32		1725	1875	1600	1738	2896
33		0005	2960	2815	2888	2888
34	24 July	2315	4585	4930	4757	4855
35		2350	2790	2975	2883	2883
36	25 July	1635	2710	3125	2918	5305
37	24 July	2300	635	745	690	711
38		2240	995	970	983	1023
39		2230	1270	1115	1192	1242
40		2200	3230	3030	3130	3277
41		2100	1160	1020	1090	1313
42						
43		2045	1595	1595	1595	2019
44		2030	725	730	728	970
45		2015	1235	1240	1238	1768
46		2000	440	500	470	746

Plot	Date	Time	Observer C	Observer E	$\bar{x}$	Time Comp.
47		1955	735	885	810	1285
48		1945	560	600	580	966
49		1940	425	355	390	650
50		1900	3145	3855	3500	6034
51		1840	2155	2190	2173	3811
52	22 July	1900	1220	1110	1165	2080
53		1920	1000	920	960	1627
54		1950	1640	1385	1513	2440
55		2000	1170	1190	1180	1903
56	21 July	2100	2890	2610	2750	3055
57		2130	3195	3460	3328	3502
58		2210	2800	3380	3090	3090
59		2300	4350	4535	4443	4487
60		0035	1560	1890	172.5	1816
61		0045	4140	3450	3795	4081
62		0115	3190	4020	3605	4097
63	22 July	1700	1750	1990	1870	3016
64		1500	1540	1880	1710	2758
65		1526	1930	2090	2010	3190
66		1535	1310	1360	1335	2119
67		1615	920	1120	1020	1594
68		1625	2000	1935	1968	3124
69		1645	440	370	405	653
70		2200	1270	1140	1205	1205
71		2215	1430	1390	1410	1410
72		2225	830	860	845	845
73		2230	1080	990	1035	1035
74		2240	1250	1430	1340	1340
75		2300	..	260	260	263
Total :			129,068	133,775	131,420	183,659

Table 11. Compensation counts of murres; Cape Lisburne, 1977 - per cent of maximum.[1]

	July			
Time	21-22	24	25	26
1500	62			
1600	64			34
1700	62		55	47
1800	59		66	48
1900	56	57	73	69
2000	62	60	76	71
2100	90	.79	82	77
2200	100	97	100	87
2300	99	96	96	100
2400	99	100		91
0100	90			

[1] Max ima

21-22 July - 1629

24 July - 1298

25 July - 836

26 July - 712

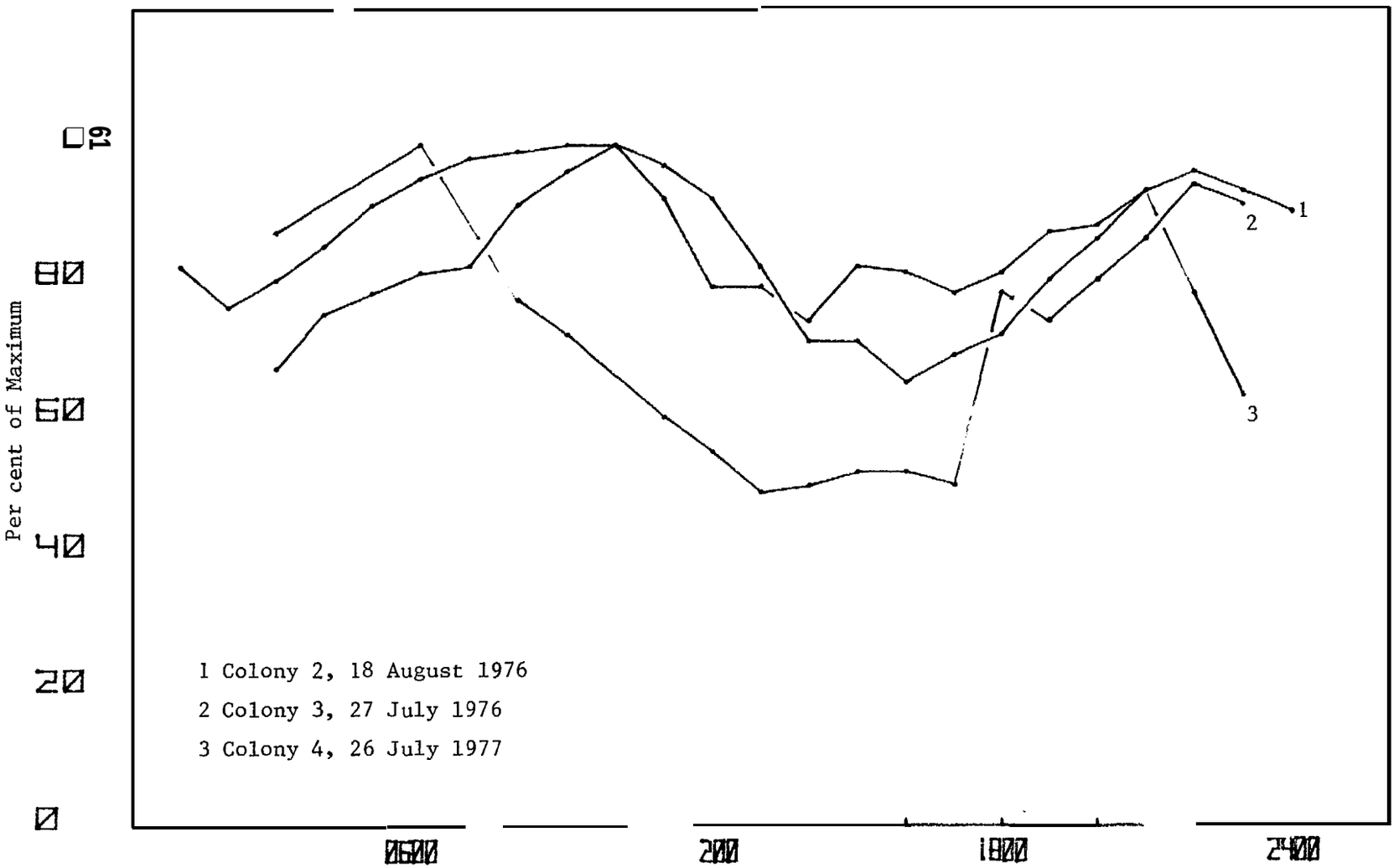


Figure 6. Diurnal activity patterns of murres at Cape Thompson.

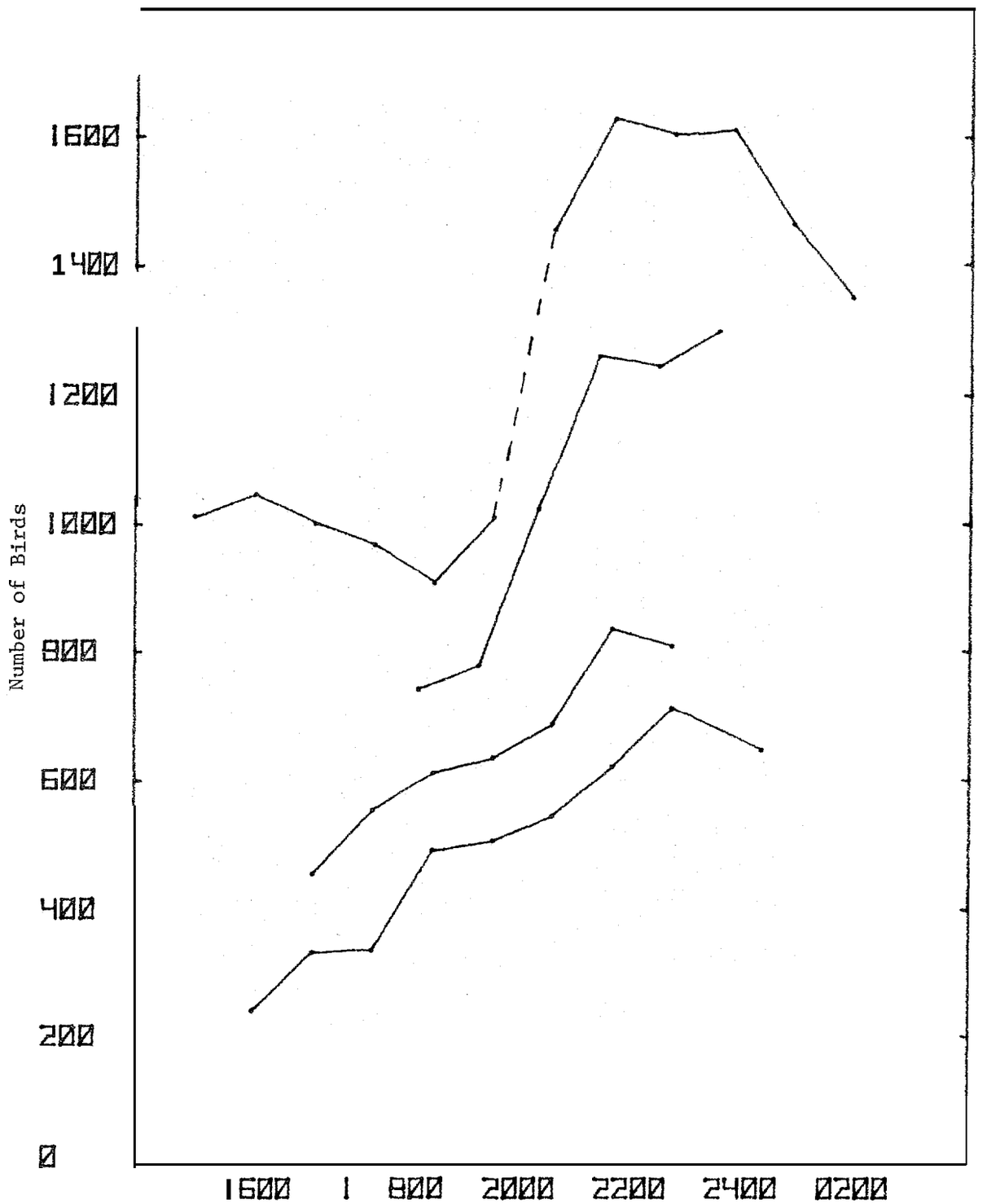


Figure 1. Diurnal activity patterns of murres at Cape Lisburne.

chronization *of the movements of birds on the compensation plots. This same regularity was observed in the movement of birds between the feeding grounds and the colonies. Five-minute counts of birds flying towards the colonies from feeding areas were made on 7-8 July. Similar counts were not made at Cape Thompson this summer; however, the timing of this activity at Cape Lisburne was essentially congruent with that observed in 1976 at Cape Thompson (see Figure 8).*

The regularity of the movements of birds to and from feeding areas at Cape Lisburne was remarkable,however, no more so than were the numbers of birds involved. In 1976 at Cape Thompson we counted birds during 15 minutes of each hour, an interval which we felt allowed sufficient birds to pass by our observation point to provide a good estimate of numbers. The greatest number counted during any of the 15-minute counts was 1952 birds, which equals about 7800 birds per hour. We also had expected to make 15-minute counts in 1977 at Cape Lisburne. Our first count, however, corresponded with the peak movement of birds returning to the cliffs and after five minutes the average of two observers' counts was 4300 individuals, or 51,600 birds per hour. Most of the flocks of murres returning to the colonies contained in the order of 100 birds, with a range of about 25 to about 700. The flocks were highly visible and could often be seen several kilometers away.

The magnitude of the movements of birds to and from the colonies complicates our estimate of the population size of murres at Cape Lisburne. If we add the numbers of murres estimated to have passed by the site on their return to the colonies between the peak time, 1900 hours, and midnight, we obtain a total of about 167,000 murres. We counted birds leaving the colonies toward feeding areas during the same times that counts were made of birds returning. The flocks leaving the colonies were small, generally not larger than 25 birds, and flew very near the water making them difficult to see. Between 1900 hours and midnight, we estimate that at least 49,000 murres flew away from the colonies.

We do not know what the circuit time for murres is between the colonies and the feeding grounds. Neither do we know that all of the birds observed leaving the colonies during our counts were, in fact, going to the feeding grounds, or whether they simply made a large circle and joined birds returning to the colonies. We are certain, however, that large numbers of murres were away from the colonies even at the times of peak attendance on the ledges as determined by the compensation count. Our estimate of the population therefore probably represents a minimum, and the actual number of murres at Cape Lisburne may well be in excess of 200,000.

Phenology

The timing of the events in the reproductive cycles of murres at Cape Thompson during 1977 appears to have been about a week to ten days earlier than in 1976 and 1959, and about the same or perhaps a little later than in 1960 and 1961. This conclusion is based on gonadal and brood patch development of the birds we collected as well as on observations of egg-laying and hatching and the sea-going of chicks.

Table 12 presents testes volumes and follicle sizes, and Table 13 presents brood patch development (see Swartz 1966) of Thick-billed Murres collected at intervals during last summer. These data are compared to those of 1960 and 1976 in Figures 9, 10, 11 and 12. Maximum gonadal development

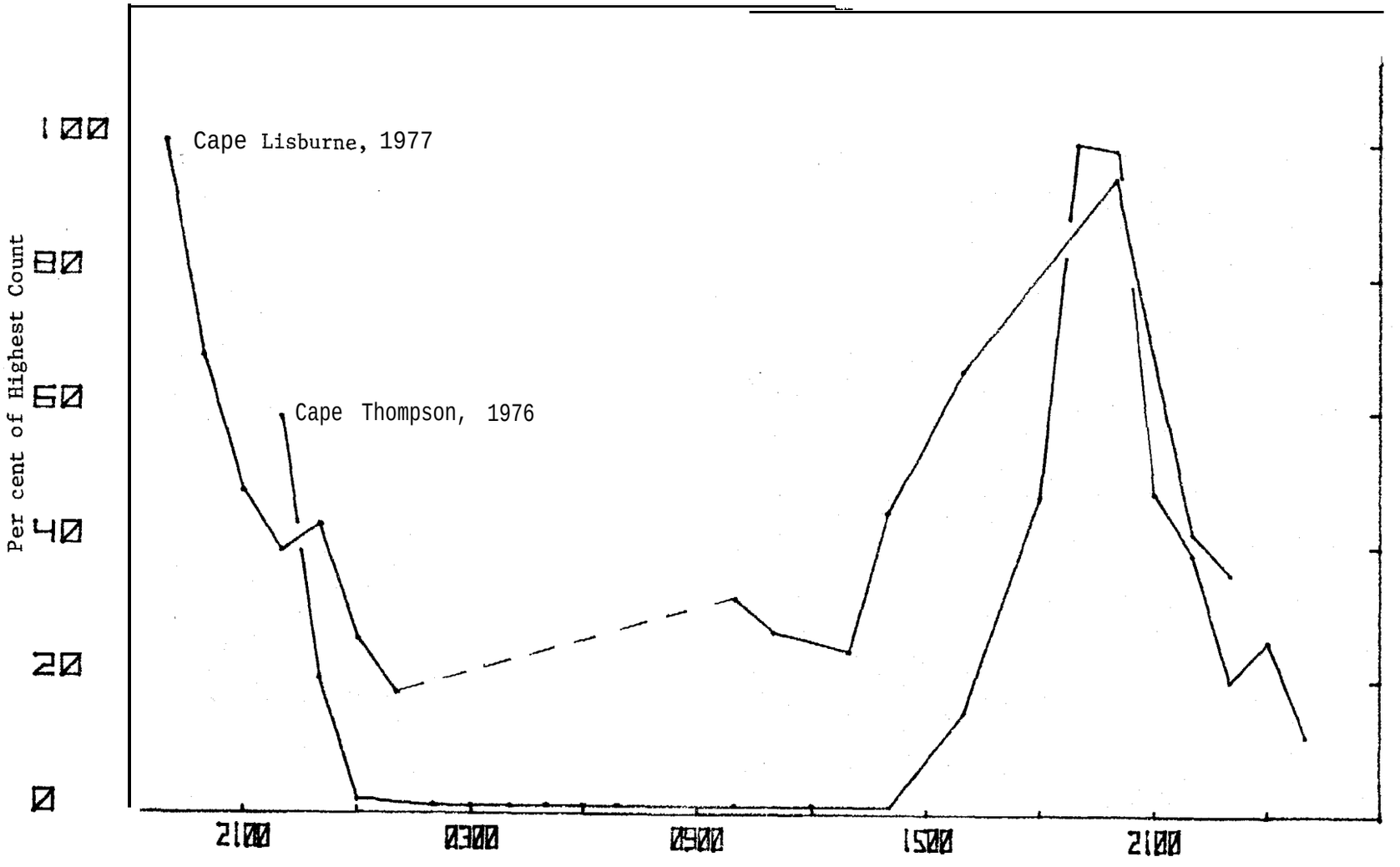


Figure 8. Movements of murres between feeding areas and the colonies.

Table 12. Testes volumes (in cubic centimeters) and diameters of largest ovarian follicles (in millimeters) of male and female Thick-billed Murres collected at Cape Thompson, 1977.

Period	Left		Right		Follicles	
	n	Average volume	n	Average volume	n	Average diameter
8 June	8	3.65±2.13	8	2.10±0.72	3	5.17±0.29
21 June	9	4.13±0.89	9	3.07±1.30	9	9.28*3.42
12-13 July	5	1.71±1.09			3	7.1 ±1.67
6-11 Aug	18	0.25±0.25	14	0.17±0.16	10	3.17±0.68
13-17 Aug	14	0.20±0.16	14	0.12±0.08	7	3.17±0.51
21-24 Aug	8	0.16±0.11	7	0.10*0.03	8	2.95?0.45

Table 13. Brood patch development of Thick-billed Murres collected at Cape Thompson, 1977.

Period	Males		Females	
	n	Average class value	n	Average class value
8 June	8	0	3	0
21 June	11	1.2	9	0.4
12 July	3	2.3	3	2.0
6-11 Aug	18	2.9	10	2.2
13-17 Aug	14	3.6	7	3.7
21-23 Aug	9	4.6	8	4.0

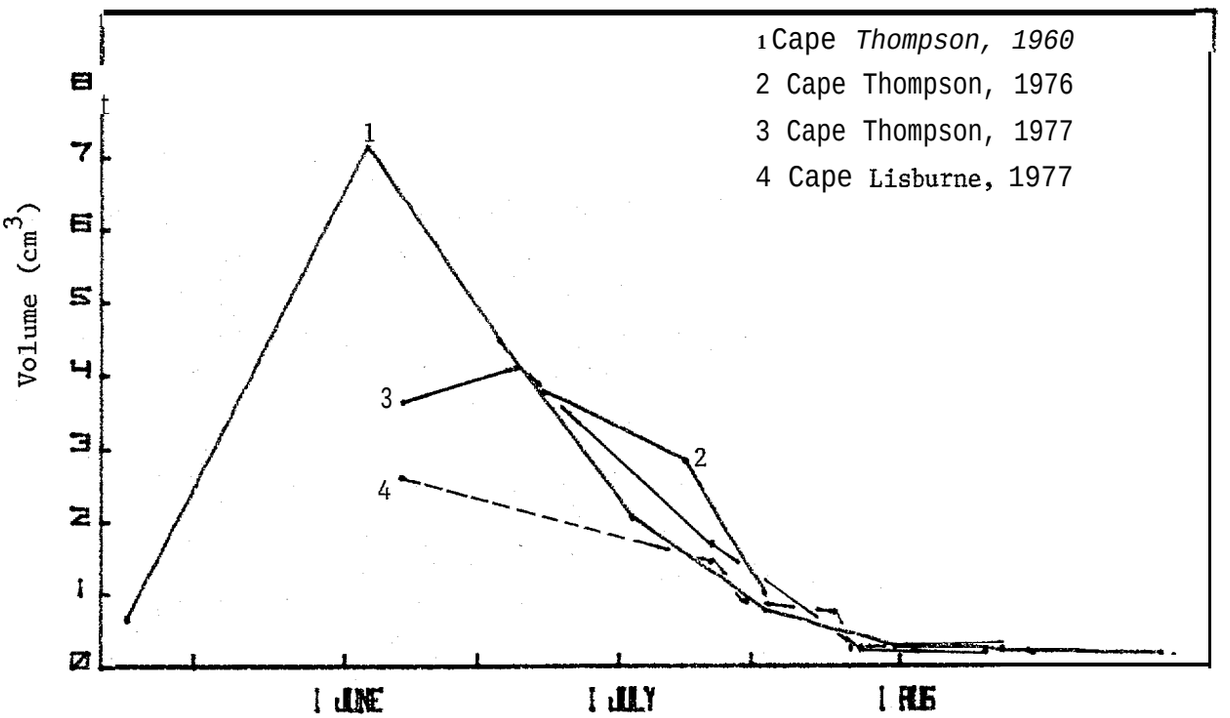


Figure 9. Testicular development of Thick-billed Murres at Cape Thompson and Cape Lisburne.

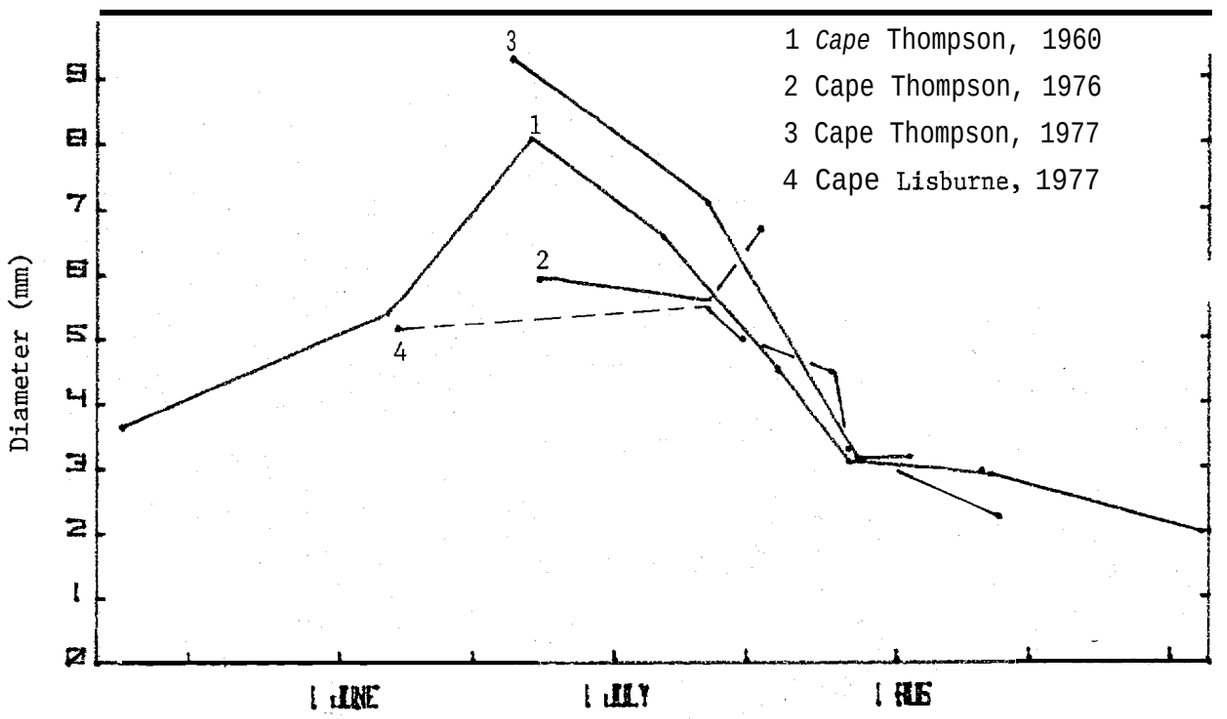


Figure 10. Follicular development of Thick-billed Murres at Cape Thompson and Cape Lisburne

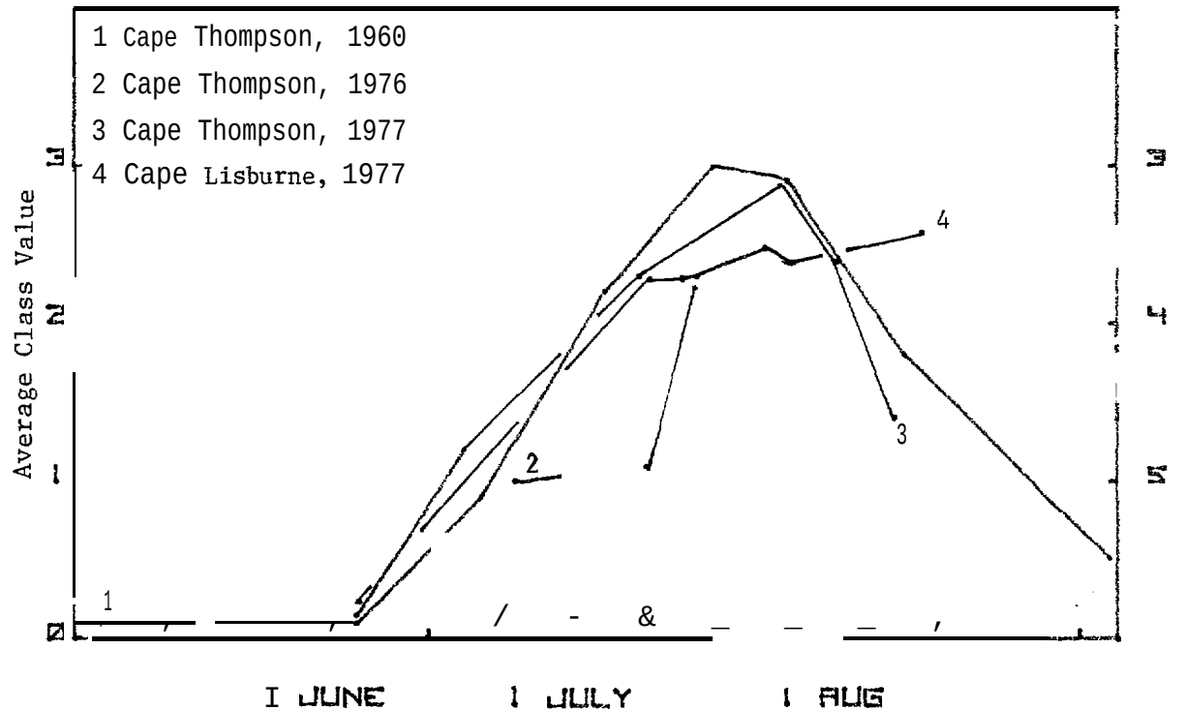


Figure 11. Brood patch development of male Thick-billed Murres at Cape Thompson and Cape Lisburne.

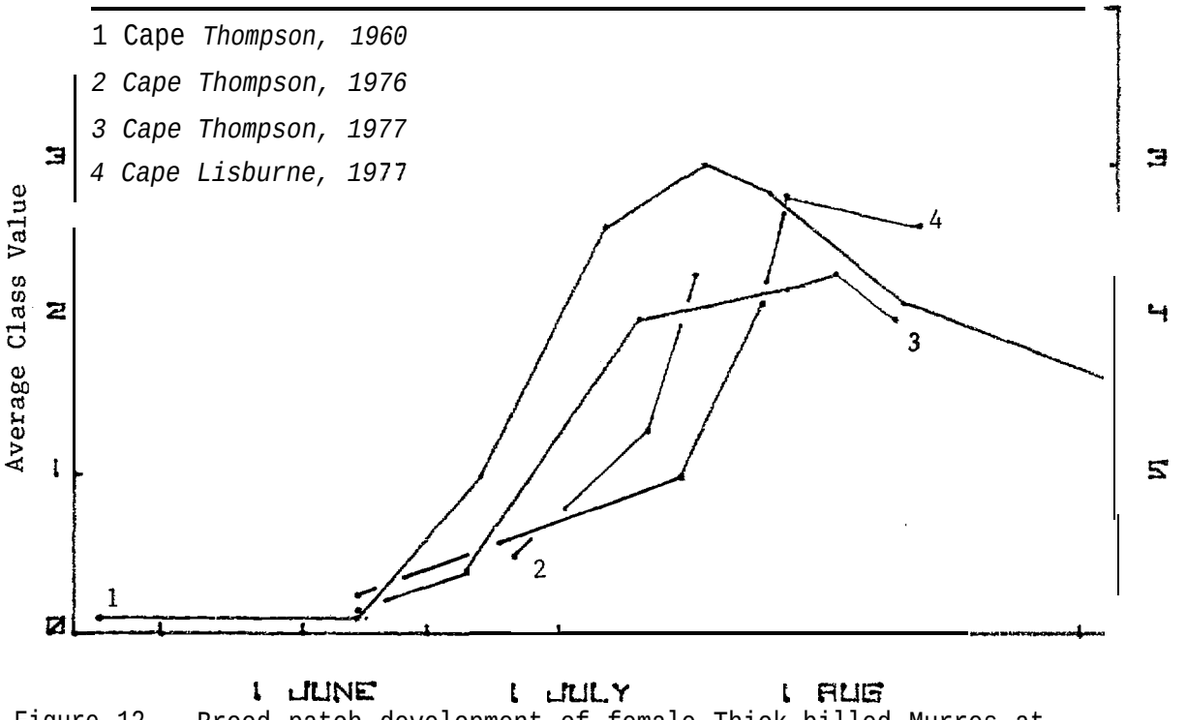


Figure 12. Brood patch development of female Thick-billed Murres at Cape *Thompson and Cape Lisburne.*

in 1977 of both males and females was seen in the sample collected on 21 June, and maximum brood patch development in both sexes was seen in the sample collected 6-11 August. In 1960 maximum development of testes occurred during the period 1-15 June, however, the greatest average diameter of ovarian follicles was not seen until 16-30 June, the same period as in 1977. Maximum development of brood patches in both sexes from 1960 occurred during the latter two weeks of July.

No maxima of gonadal development or brood patch development were seen in the birds collected during 1976. This is due in part to the relatively short time during which murres were collected; however, collections were made during the time when maxima would be expected to occur. The 1976 data suggested a lack of synchronization in the reproductive effort of the birds on a colony-wide basis and, together with laying and hatching dates, suggested a somewhat delayed breeding season.

Upon our arrival at Cape Thompson on 6 July 1977, many murres had already laid eggs. The first chick sighted, a Thick-billed Murre, was on 1 August. If 34 days is used as a mean incubation period for murre eggs (see Tuck 1960), then that egg must have been laid approximately 25-26 June. The majority of eggs was probably laid between 1-8 July and hatched about 4-12 August. One egg hatched on 23 August and others may have hatched as late as the first week in September.

The first sea-going of murre chicks was observed on 23 August. A large, well-developed chick was found swimming out to sea with an adult Thick-billed Murre at Colony 2. Calling-off activity began about 21 August and continued through our departure.

Dates of first eggs, first chicks and first sea-going for all years at Cape Thompson are presented in Table '14.

Table 14. Phenology *of nesting activities of Thick-billed* Murres *at Cape Thompson.*

Year	First Egg	First Chick	First Sea-going
1959	9 July	11 August	25 August
1960	27 June	30 July	18 August
1961	23 June	27 July	19 August
1976	4 July	9 August	*
1977	25 June	1 August	23 August

*no sea-going observed prior to our departure on 25 August

We were *unable to collect* murres *at Cape Lisburne on 21 June.* We *therefore do not have a continuous record of gonad and brood patch development in birds at Cape Lisburne for 1977. The data presented in Tables 15 and 16, when compared to similar data from Cape Thompson (see Table 12 and 13) suggest, however, that the development of reproductive physiology in* murres *at Cape Lisburne essentially paralleled that at Cape Thompson.*

Based on hatching dates, egg *laying commenced as early as 24 June and most* eggs *were probably laid during the interval 27 June to 3 July. The first chick observed was on 5 August, however, inclement weather had prevailed for several days prior to that date and observations of nesting ledges* were *not made. The size of the oldest chicks on 5 August suggested*

Table 15. Testes volumes (in cubic centimeters) and diameters of largest ovarian follicles (in millimeters) of male and female Thick-billed Murres collected at Cape Lisburne, 1977.

Period	Left		Right		Follicles	
	n	Average volume	n	Average volume	n	Average diameter
8 June	4	2.59?1.34	4	1.98±1.01	3	5.2 ±1.41
13 July	7	1.42±0.31	7	1.30±0.66	1	5.6
20 July	12	0.84?0.59	13	0.63?0.48	2	5.0 ±1.41
26-31 July	15	0.69±0.56	14	0.49±0.46	18	4.47±1.19
5-11 Aug	3	0.20±0.12	3	0.20±0.16	4	3.3 ±1.31
21-29 Aug	7	0.17±0.07	7	0.1510.07	4	2.25?0.87

Table 16. Brood patch development in Thick-billed Murres collected at Cape Lisburne, 1977.

Period	Males		Females	
	n	Average class value	n	Average class value
8 June	4	0.25	3	0
13 July	7	2.3	1	3
20 July	13	2.3	2	1
26-31 July	17	2.5	18	2.1
5-11 Aug	7	2.4	10	3.2
21-29 Aug	8	3.4	5	3.4

that the first hatch occurred about 1 August. Most eggs probably hatched between 4-7 August. On 20 August, murres were observed concentrating below the cliffs and calling to young and three large chicks were observed swimming out to sea on that date. The number of chicks leaving the cliffs increased rapidly through 25 August, and some sea-going may have continued well into September. The majority of the murre chicks probably went to sea between 23 August and the first week in September. Murres were not observed leaving the cliffs until 28 August in 1976, about a week later than this past year.

Population characteristics

Not all of the murres at Cape Lisburne exhibited complete development of reproductive condition, especially the brood patch, and we believe that those birds did not reproduce successfully during 1977. Six male and five female Thick-billed Murres were collected which had a brood patch class 0 to 1, and 38 males and 25 females were collected which had a brood patch greater than or equal to 2, Ten Common Murres, five males and five females, were collected which had brood patch development of 0 or 1, and 18 birds, 9 males and 9 females, were collected which had brood patch development of 2 or greater. We have chosen the class value of 2 as the level below which successful incubation is probably unlikely to occur, and which we believe indicates a non-breeding condition. This does not imply, however, that all birds with brood patch development equal to or greater than 2 were successful breeders. These figures include only those birds which were collected after the second week of July. Birds which had not yet achieved full development during June, therefore, were excluded from the sample.

The above numbers of birds having little or no brood patch development relative to those having brood patch development greater than or equal to 2 is not representative of the population as a whole. Nineteen of the Thick-billed Murres collected at Cape Lisburne were obtained from in front of the colonies, either on the water or flying in the immediate vicinity of the cliffs. Eight (44%) of these had brood patches between 0 and 1. Among the remaining 55 birds on which we have brood patch data and which were all collected while returning to the cliffs from feeding areas, four (7.3%) had brood patches of 0 or 1. Fifteen Common Murres were collected from off the water or in the air in the vicinity of the cliffs, 10 (66%) of which had brood patch development of 0 or 1. None of the birds collected returning to the cliffs from sea had brood patches less than 2. These data suggest that the murres which are probable non-breeders tend to remain close to the colonies and may not feed a great distance away, or as will be discussed in a following section, may feed away from the colonies at a different time than do the breeding birds.

We collected birds generally during the evening when the largest numbers were returning to the cliffs from their feeding grounds, a practice which tended to increase our success ratios. Table 17 lists the dates, times and genders of birds collected at Cape Lisburne during July. The majority of the birds collected returning to the cliffs, 81%, were males. By 30 July we *had recognized this pattern and collected birds which were not only returning to the cliffs but which were leaving the* cliffs *at the same time. Only 43% of the birds collected leaving the cliffs were males, while 57% were females. The six males collected on*

Table 17. Proportions of male and female Thick-billed Murres collected during July at Cape Lisburne.

Direction of Flight	Date	Time	No. Males	No. Females
Toward colonies	13 July	2200	5	1
Toward colonies	20 July	2200	10	1
Toward colonies	30 July	0100	7	3
Toward sea	30 July	0100	6	8

Table 18. Average weights of male Thick-billed Murres collected during July at Cape Lisburne.

Direction of Flight	Date	N	Average Weight
Toward colonies	13 July	5	1019±62
Toward colonies	20 July	10	1032±70
Toward colonies	30 July	7	1043*45
Toward sea	30 July	6	966±65

30 July as they were leaving the colonies weighed less than any of the male groups collected which were returning to the cliffs, as shown in Table 18. The difference in weight between the two groups of males collected on the same date, 30 July, *was* statistically significant ($t = 2.5$; $P<0.05$). No correlation was seen between the weight of individual birds and the per cent fullness of the respective stomachs.

We are not certain what the biological significance of the observed weight difference between males is. The weights of Thick-billed Murres which had brood patches of 0 or 1 averaged less than the weights of Thick-billed Murres which had brood patches of 2 or more, and these differences were significant. These data are presented in Table 19. Murres which bred at the periphery of the colony also tended to weigh less than the average for all 'breeding birds.' This was first noticed when murres were captured alive for radio telemetry studies. The only birds which were readily accessible were those which were on the edges of the colony and they were noticeably lighter and smaller. Therefore, on 28 August, four birds were collected from the east edge of the colonies at Cape Lisburne. Three females weighed an average of 906±46 grams and one male weighed 890 grams. Although all of the birds were relatively light, they had well developed brood patches and were assumed to be breeding since chicks and eggs were visible on the ledges from which these birds were collected.

Table 19. Comparisons of body weights of Thick-billed and Common Murres at Cape Lisburne.

	Thick-billed Murres				Common Murres,			
Brood Patch	Males	n	Females	n	Males	n	Females	n
0-1	908±43	6	866±36	5	888±53	5	934±24	5
≥ 2	1010±60	38	957±79	25	988±60	9	957±74	9
t	3.99		2.55		3.10		0.67	
P	<0.001		<0.02		<0.01		<0.6	

Whether or not the smaller murres are relatively younger, relatively less fit or only smaller than the larger birds is not known. These observations suggest, however, that smaller murres and females may be temporally segregated from the majority of the large males on the feeding grounds. Furthermore, small murres also may tend to be spatially segregated from larger birds within the breeding colony.

Food habits

The food items identified from stomach contents of Thick-billed Murres collected at Cape Thompson and Cape Lisburne in 1977 are presented in Table 20, as well as food habits data from 1960 and 1976 at Cape Thompson. Food items of Common Murres from all years are presented in Table 21. The data presented in these tables suggest that inter-year and inter-colony differences and similarities in the overall utilization of certain food groups and individual species exist for both Thick-billed and

Table 20. Food of Thick-billed Murres at Cape Thompson and Cape Lisburne, Alaska. Percent occurrence of food items refers only to those stomachs containing food; values in parentheses refer to the total sample.

	Cape Thompson						Cape Lisburne	
	1960		1976		1977		1977	
	n	%	n	%	n	%	n	%
Total examined	176		52		108		84	
Number empty	43	(24.4)	1	(2)	26	(24)	13	(15)
Frequency of invertebrates	45	33.8	40	78	53	65	43	61
Frequency of fish	85	63.9	39	76	69	84	64	90
FISH:								
Gadidae					16	20	17	24
Boreogadus saida	60	45.1	13	25	5	6	14	20
Eleginus gracilis			4	8	18	22	4	6
Cottidae	1	0.8	5	10	6	7	17	24
Triglops forficata	1	0.8						
Myoxocephalus quadricornis	6	4.5	1	2	3	4	1	1
Myoxocephalus sp.	3	2.3	8	16	25	30	7	10
Artidiellus sp.			4	8	9	11	4	6
Gymnocanthus galeatus					6	7		
Icelinus sp.					3	4	1	1
Hemilepidotus jordani							3	4
Zoarcidae								
Bothrocara sp.			6	12				
Lycodes sp.			1	2				
Ammodytes hexapterus	12	9	2	4	24	29	16	23
Mallotus villosus			1	2	5	6		
Liparus sp.			1	2	12	15	8	11
Chirolophus polyactocephalus	1	0.8						
Stichaeus punctatus	1	0.8			1	1		
Lyconectes aleuticus							1	1
Pleuronectidae	3	2.3						
Unidentifiable	*10*	7.5	8	16	3	4	6	8
INVERTEBRATES :								
Polychaeta	12	9			2	3	1	1
Polynoidae	2	1.5						
Nereis *sp.*			9	18	3	4	6	8
Mollusca					3	4		
Gastropoda			7	14	8	10	6	8

	Cape Thompson						Cape Lisburne	
	1960		1976		1977		1977	
	n	%	n	%	n	%	n	%
INVERTEBRATES, continued								
Trochidae	2	1.5						
Naticidae	7	5.3						
Natica sp.	3	2.3			1	1		
Clausa sp.	1	0.8						
Pteropoda	1	0.8						
Arthropoda					5	6	6	8
Amphipoda			1	2	3	4	4	6
Gammaridae			4	8	3	4	5	7
Koroga megalops					12	15	6	8
Gammaridae sp. 1	1	0.8			1	1		
Gammaridae sp. 2	1	0.8			1	1	1	1
Hyperidae							7	10
Hyperia sp.							2	3
Copepoda					4	5		
Curnac ea					2	3		
Euphausiacea					1	1	5	7
Decapoda					6	7	1	1
Pandalidae								
Pandalus sp.			2	4	2	3	2	3
P. goniurus			7	14	2	2	6	8
P. jordani					3	4	13	18
P. montagui			3	6			1	1
Hippolytidae	2	1.5						
Eualus gaimardi			6	12				
Lebbius groenlandicus			3	6				
Crangonidae			3	6	1	1		
Notocrangon argis	1	0.8						
Shrimp remnants	6	4.5	*15*	29	11	13	9	13
Paguridae	3	2.3	*1*	2				
Crab remnants			*2*	4	3	4	1	1
Unidentified invertebrates	15	11.3	6	12				
MISCELLANEOUS								
Foraminifera					1	1	2	3
Hydroids					1	1	1	1
Barnacle					2	2	1	1
Algae	1	(0.6)	2	4				
Pebbles	48	(27.3)	14	(27)	55	(51)	34	(40)

Table 21. Food of Common Murres at Cape Thompson and Cape Lisburne, Alaska. Percent occurrence of food items refers only to those stomachs containing food; values in parentheses refer to the total sample.

	Cape Thompson						Cape Lisburne	
	1960		1976		1977		1977	
	n	%	n	%	n	%	n	%
Total examined	84		20		20		28	
Number empty	18	(21.4)	8	(40)	5	(25)	7	(25)
Frequency of invertebrates	4	6.1	4	33	2	13	4	19
Frequency of fish	63	95.s	11	92	15	100	21	100
FISH :								
Gadidae	1	1.5	1	8	2	13	9	43
Boreogadus saida	51	77.3	5	42	3	20	6	29
Boreogadus sp.	2	3						
Eleginus gracilis			4	33	2	13	5	24
Cottidae			2	17	1	7	3	14
Triglops sp.	1	1.5						
Myoxocephalus sp.	1	1.5			1	7		
Icelinus sp.					1	7		
Lycodes sp.			1	8				
Ammodytes hexapterus	18	27.3	2	17	12	80	12	57
Ammodytes sp.	2	3						
Mallotus villosus					4	27		
Liparus sp.							1	5
Chirolophus polyactocephalus	1	1.5						
Pleuronectidae	4	6.1						
Unidentifiable	5	7.6	1	8	1	7	2	10
INVERTEBRATES :								
Polychaeta	4	6.1					1	5
Nereis sp.							1	5
Pteropoda							1	5
Limacina helicina								
Ostracoda					1	7	1	5
Arthropoda					1	7		
Amphipoda	1	1.5	1	8				
Gammaridae			2	17				
Euphausiacea							1	5
Decapoda								
Pandalus sp.			1	8			1	5
Eualus gaimardi			1	8				
Shrimp remnants	1	1.5						

	Cape *Thompson*						Cape Lisburne	
	1960		1976		1977		1977	
	n	%	n	%	n	%	n	%
INVERTEBRATES, continued								
Unidentified invertebrates	1	1.5						
MISCELLANEOUS								
Algae	1	(1.2)						
Pebbles	20	(23.8)	4	(33)	4	(20)	3	(11)

Common Murres.

Cod (Gadidae) were important to both species of murres in all years. Arctic Cod (Boreogadus saida) may be utilized somewhat more heavily than Saffron Cod (Eleginus gracilis) although the differences were not great except in 1960 when Saffron Cod were not identified from stomachs contents of either murre species.

A total of six species of sculpin (Cottidae) has been identified from the stomach contents of Thick-billed Murres. That group of fish also appears to be relatively important in the birds' diet. On the other hand, Common Murres utilized sculpin with a very low frequency and they are probably of only minor significance to those birds.

The only year in which eelpouts (Zoarcidae), especially Bothrocara sp., occurred was in 1976 when they may have been relatively important to Thick-billed Murres. Eelpouts have not been identified in food remains of Common Murres at either colony in any year. Sand Launce (Ammodytes hexapterus) were identified frequently at both colonies in all years except 1976 at Cape Thompson. Capelin (Mallotus villosus) appear to be taken in relatively small numbers. Snail-fish (Liparus sp.) were important to Thick-billed Murres except at Cape Thompson in 1960, although only one was identified in the stomach contents of Common Murres.

A rather wide variety of invertebrate prey has been identified from stomach contents of Thick-billed Murres, especially in 1977. Polychaetes and molluscs appear to have been taken in about equal numbers all years. Amphipods were taken relatively frequently in 1977 at both Cape Thompson and Cape Lisburne. Decapods, particularly Pandalid shrimp were probably the most important invertebrates taken by Thick-billed Murres in 1977 at both colonies, and in 1976 at Cape Thompson, although they appear to have been utilized much less at Cape Thompson in 1960.

The importance of invertebrates to Common Murres can hardly be understated. The only possible exception to this was the utilization of polychaetes at Cape Thompson in 1960. The noticeable absence of invertebrates in the stomach contents of Common Murres suggests that trophic differences between the murre species do exist at Cape Thompson and Cape Lisburne. The degree of separation can be seen in Figures 13 and 14 which summarize the frequency of fish and invertebrate utilization in both species.

The relationships illustrated in Figures 13 and 14 also suggest yearly differences in the relative utilization of fish and invertebrates by both murre species. The year which had the smallest ratio of fish: invertebrates was at Cape Thompson in 1976. The ratios were about equal at both colonies in 1977 and were about midway between 1960 and 1976.

Seasonal differences in the utilization of fish and invertebrates by Thick-billed Murres in 1977 can be seen in Figures 15 and 16. At both Cape Thompson and Cape Lisburne invertebrates appear to have been taken somewhat more often than were fish during early summer. This relationship appears to have existed through 21 June at Cape Thompson; however, on 13 July and on every other sampling date thereafter at both colonies fish were taken more frequently than invertebrates.

Figure 17 illustrates similar data for Cape Thompson in 1976. During that summer, however, the relationships changed several times and no indication about the overall importance of fish compared to invertebrates appeared.

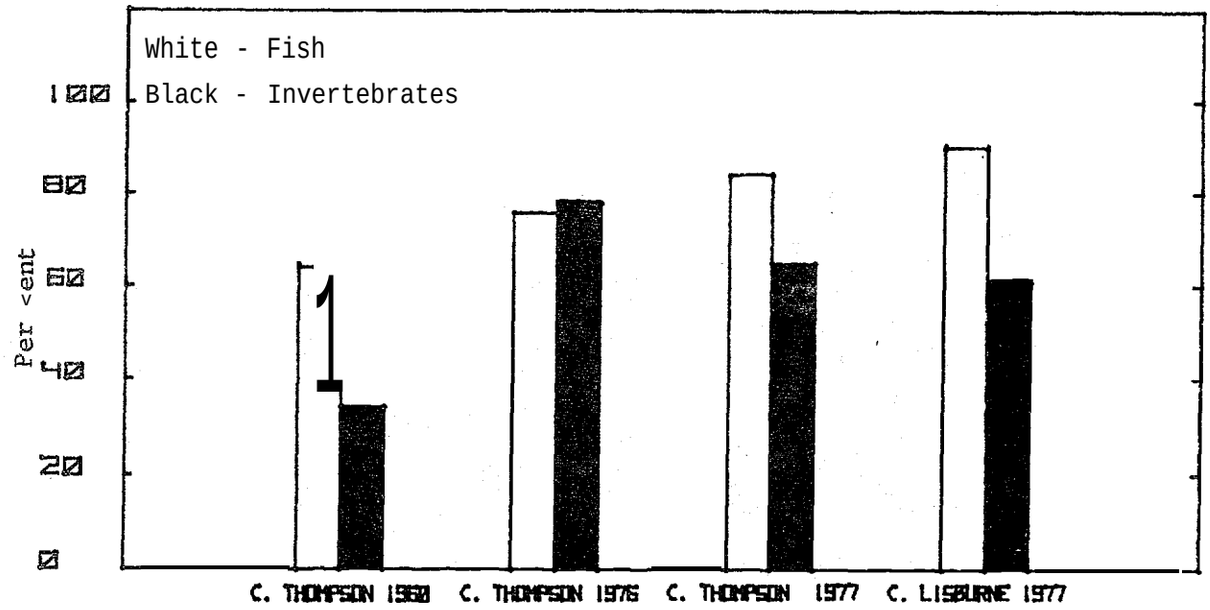


Figure 13. Relative occurrence of fish and invertebrate in stomach contents of Thick-billed Murres collected at Cape Thompson and Cape Lisburne.

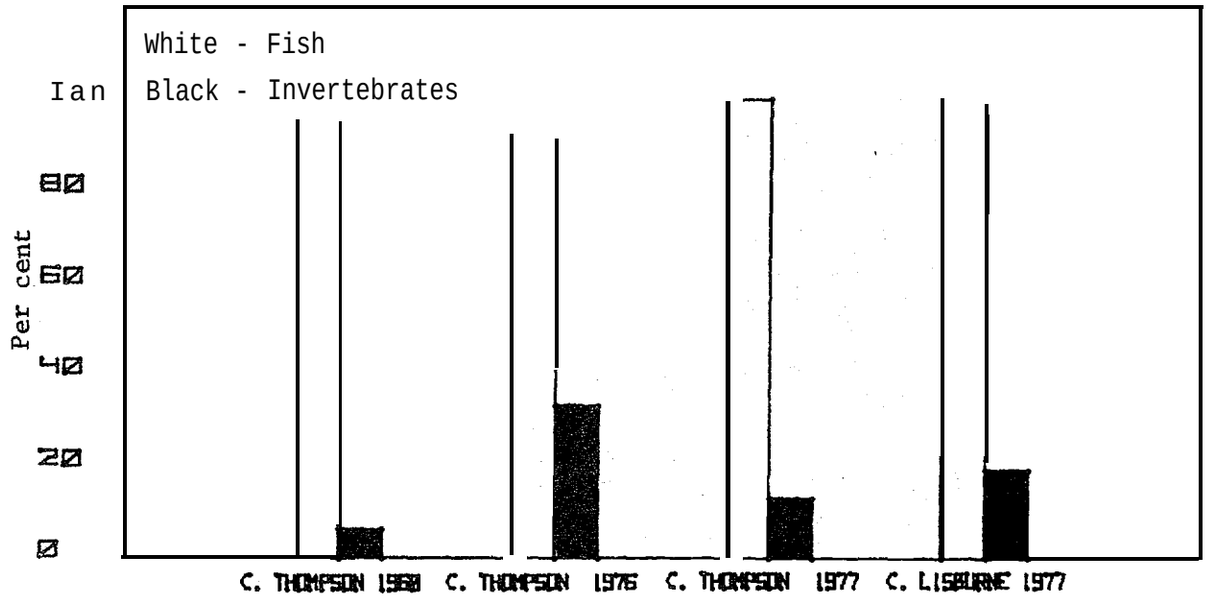


Figure 14. Relative occurrence of fish and invertebrates in stomach contents of Common Murres collected at Cape Thompson and Cape Lisburne

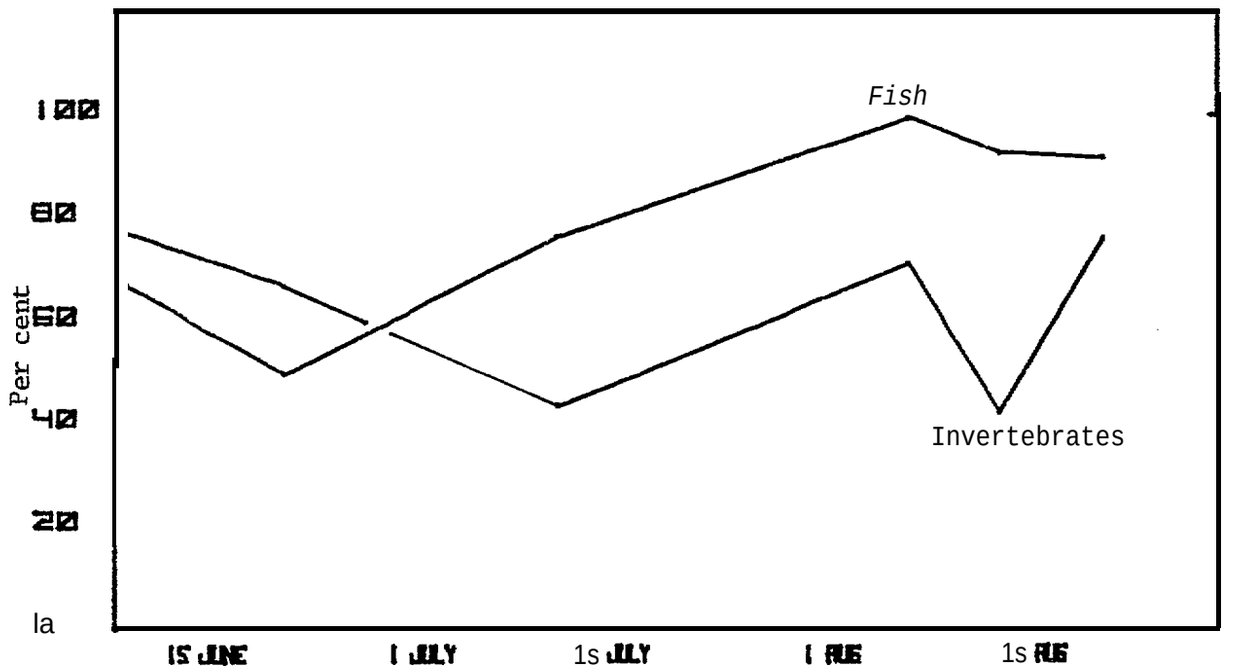


Figure 15. Seasonal utilization of fish and invertebrates by Thick-billed Murres at Cape Thompson, 1977

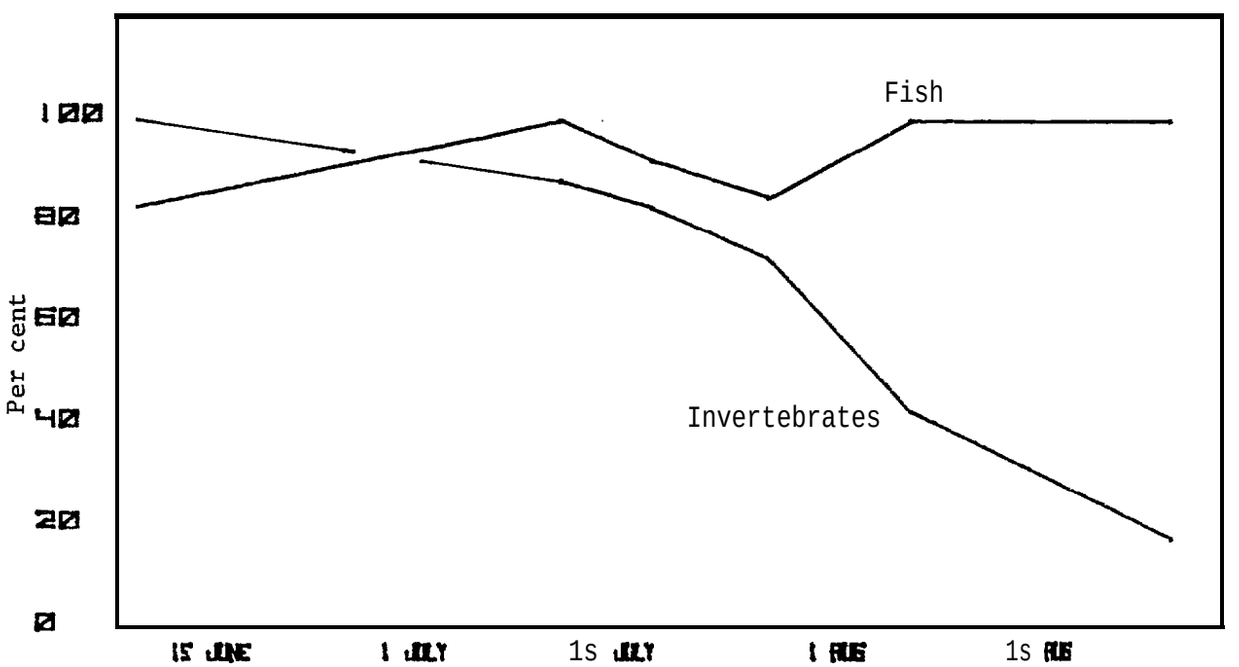


Figure 16. Seasonal utilization of fish and invertebrates by Thick-billed Murres at Cape Lisburne, 1977.

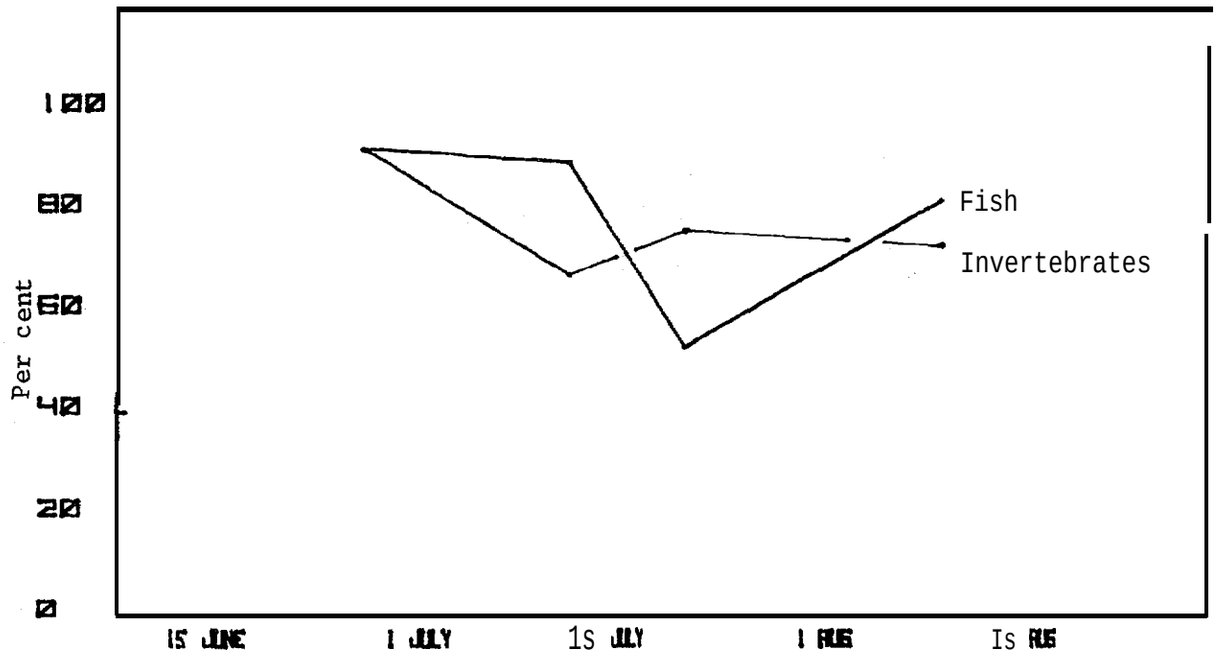


Figure 17. Seasonal utilization of fish and invertebrates by Thick-billed Murres at Cape Thompson, 1976.

Seasonal differences in the utilization of major fish groups and in the principle invertebrate prey, decapods, can also be seen. Table 22-24 present the frequency of occurrence of major food groups of Thick-billed Murres throughout the summers at Cape Thompson in 1976, Cape Thompson in 1977, and Cape Lisburne in 1977, respectively. Changes in the utilization of individual food groups throughout the summers are illustrated and compared between years and between colonies in Figures 18-22.

A pattern appears to exist in the utilization of cod by Thick-billed Murres; a peak occurred during mid-July in both years at Cape Thompson and in 1977 at Cape Lisburne. A concomitant low during mid-July in the utilization of sculpin was seen at Cape Thompson in both years with a peak occurring during the first week of August. This pattern did not exist at Cape Lisburne where sculpin were used much more evenly throughout the summer.

Sand Launce were not uncommon in the 8 June sample of thick-bills from Cape Lisburne. They were not identified at Cape Thompson until 13 July 1977, although they were not identified at Cape Lisburne on that date. During the following month the frequency with which Sand Launce were found in murre stomachs in both colonies increased rapidly. In 1976, Sand Launce were utilized infrequently and no changes similar to those in 1977 were seen.

No major differences were apparent in the utilization of snail-fish by murres at either colony in 1977. At Cape Thompson in 1976 Snail-fish were not identified, but eelpouts were and may have been utilized fairly often during mid-August.

Decapods, perhaps the principle invertebrate prey of thick-bills, were taken by a high percentage of birds during early summer at both Cape Thompson and Cape Lisburne in 1977. The importance of decapods appeared to decrease, however, as the summer progressed. Decapods were taken somewhat less frequently in mid-July of 1976 than they were during late June but by mid-August they were relatively high compared to July and compared to similar data in 1977.

Foraging patterns

Swartz (1967) reported on bird distribution at sea off of the Cape Thompson-Cape Lisburne colonies. The data were gathered during Cruise 268 of the oceanographic vessel BROWN BEAR, 6-28 August 1960. These data have been summarized in Figure 23. During the 1976 and 1977 field seasons, the direction of murre and kittiwake foraging flights were observed at Cape Thompson and Cape Lisburne. In 1977 additional observations were obtained at Cape Lewis. These data are illustrated in Figures 24-26.

The majority of the Cape Thompson murre population was observed to return daily to the cliffs from a southerly (downcoast) direction in 1959-1961. Only relatively small numbers apparently returned to *the colonies from the northwest* (upcoast) *direction. Large murre flocks returning from the south, however, were common on foggy days when they appeared to follow the shoreline* (Swartz pers. comm.; Swartz unpubl. field *notes). In late July 1976, while revisiting the Cape Thompson colonies, Swartz observed flocks of murres returning from* downcoast *and recalled that these flights were quite common in June and July of 1960 and 1961, particularly* while *sea ice was still present.*

Observations made at sea during August 1960 indicated that many

Table 22. Per cent occurrence of major food groups of Thick-billed Murres at Cape Thompson, 1976.

	27 June	13 July	22 July	12 Aug.
Gadidae	31	44	24	9
Cottidae	38	0	18	91
Ammodytes	8	0	0	9
Zoarcidae	0	11	6	45
Decapoda	69	44	53	66
n	13	9	17	11

Table 23. Per cent occurrence of major food groups of Thick-billed Murres at Cape Thompson, 1977.

	June		July	"August			
	8	21	12	6	11	13-17	21-24
Gadidae	22	42	78	47	38	21	38
Cottidae	33	8	0	94	75	50	15
Ammodytes	0	0	11	18	50	36	85
Liparus	0	8	0	24	38	21	8
Decapoda	67	25	22	41	25	21	15
n	9	12	9	17	8	14	13

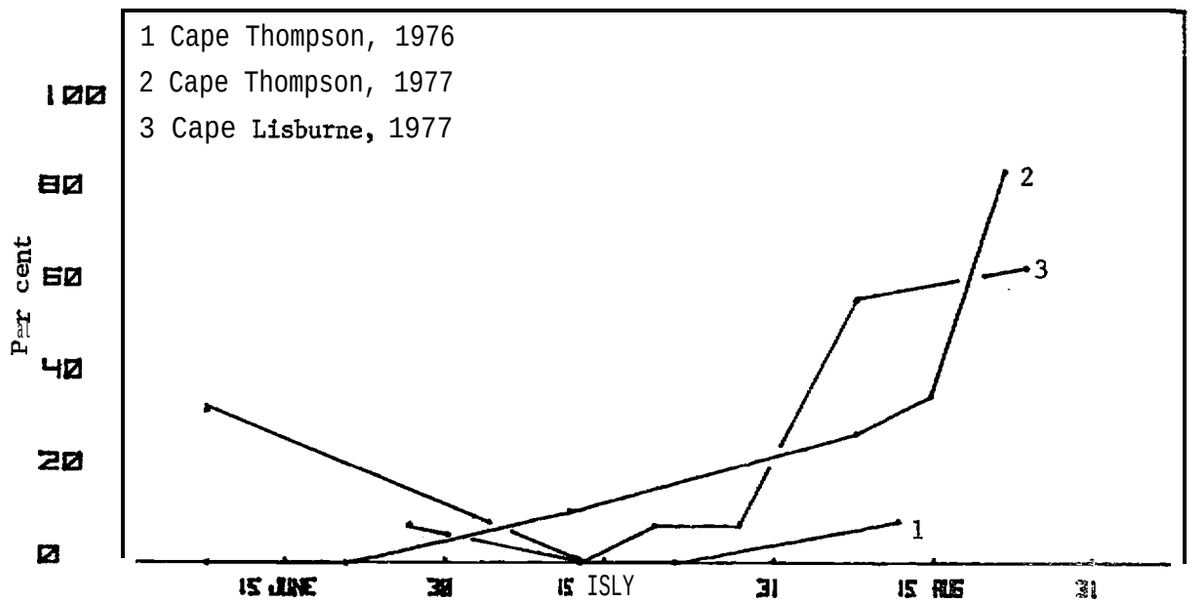


Figure 20. Seasonal utilization of Ammodytes by Thick-billed Murres at Cape Thompson and Cape Lisburne.

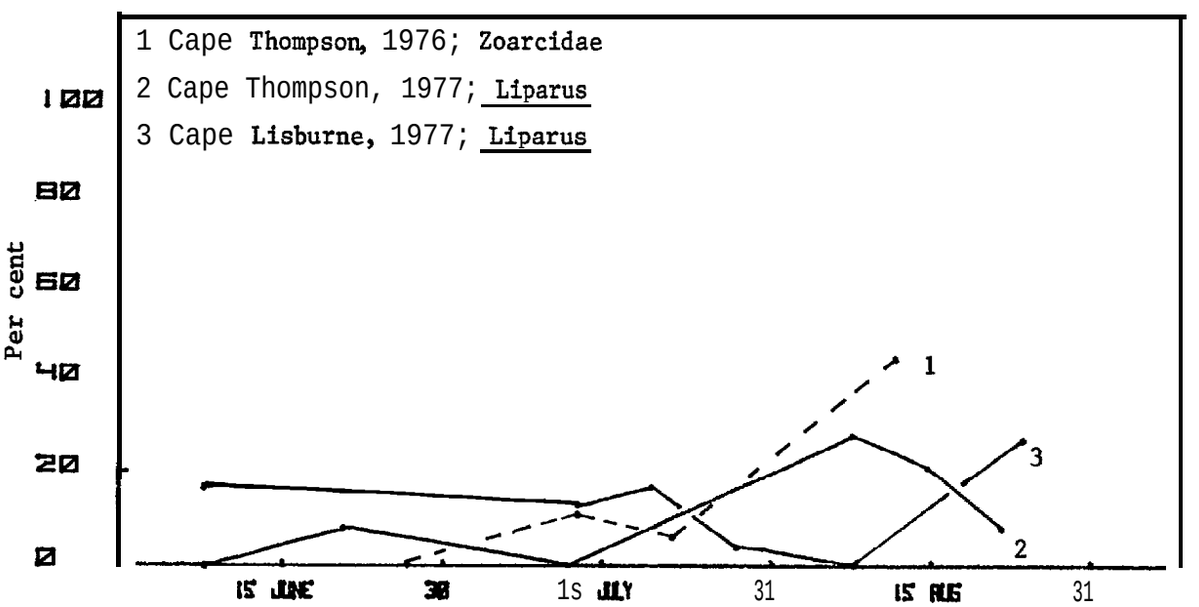


Figure 21. Seasonal utilization of Liparus and Zoarcidae by Thick-billed Murres at Cape Thompson and Cape Lisburne.

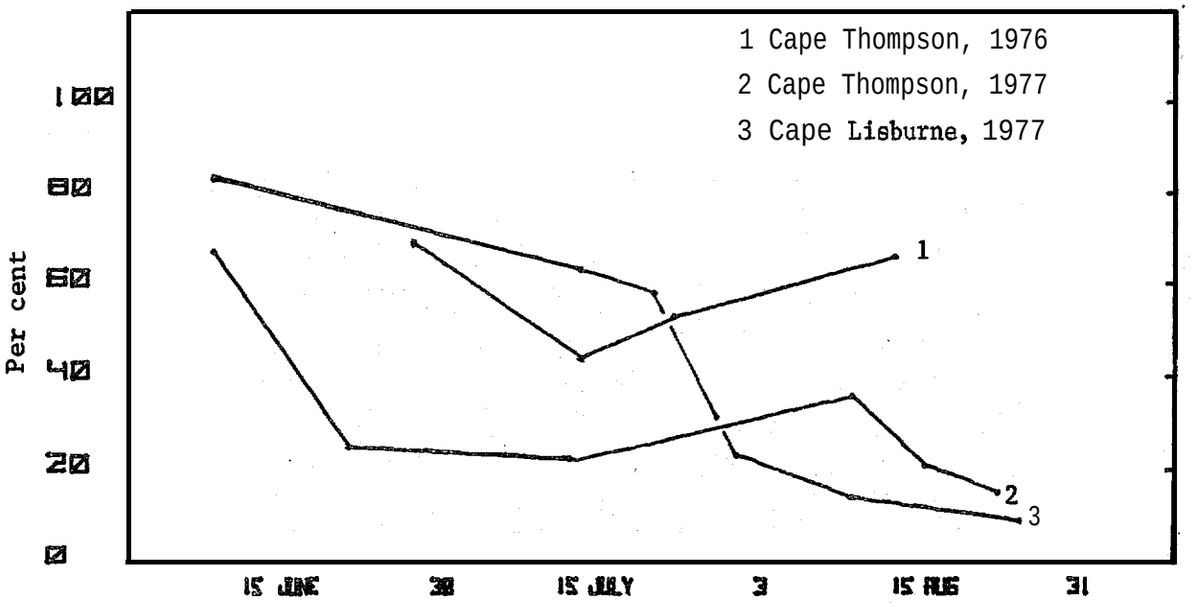


Figure 22. Seasonal utilization of Decapods by Thick-billed Murres at Cape Thompson and Cape Lisburne.

Table 24. Percent occurrence of major food groups of Thick-billed Murres at Cape Lisburne, 1977.

	June 8	July 13	July 20	July 26-31	Aug. 6-11	Aug. 21-29
Gadidae	33	75	42	62	28	27
Cottidae	33	50	58	31	43	36
Ammodytes	33	0	8	8	57	64
Liparus	17	13	17	4	0	27
Decapoda	83	63	58	23	14	9
n	6	8	12	26	7	11

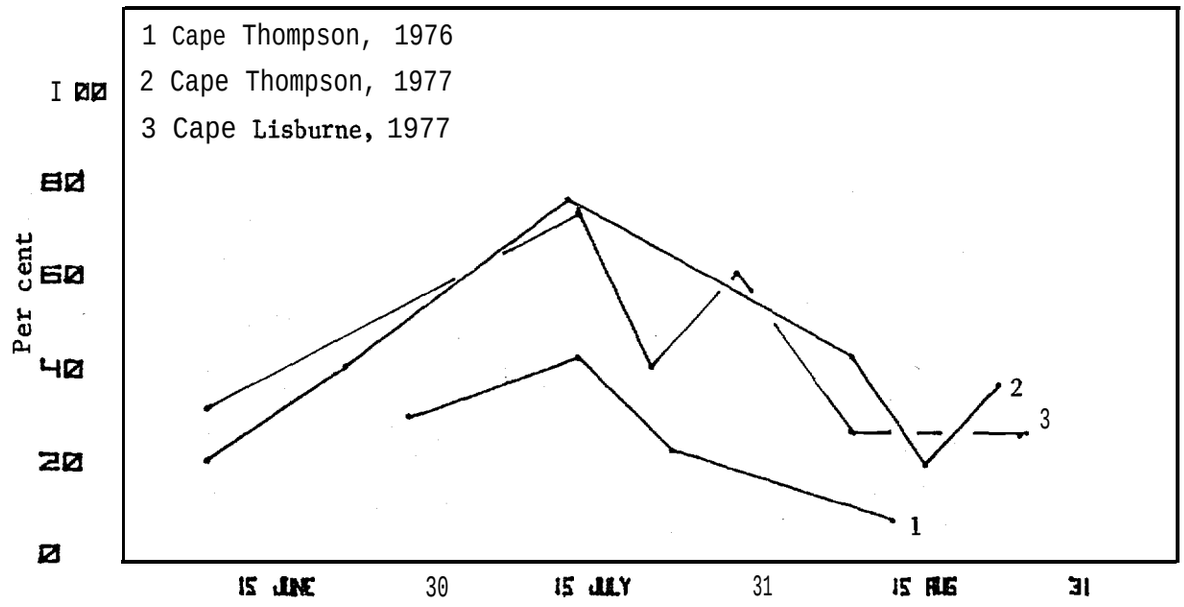


Figure 18. Seasonal utilization of Gadidae by Thick-billed Murres at Cape Thompson and Cape Lisburne.

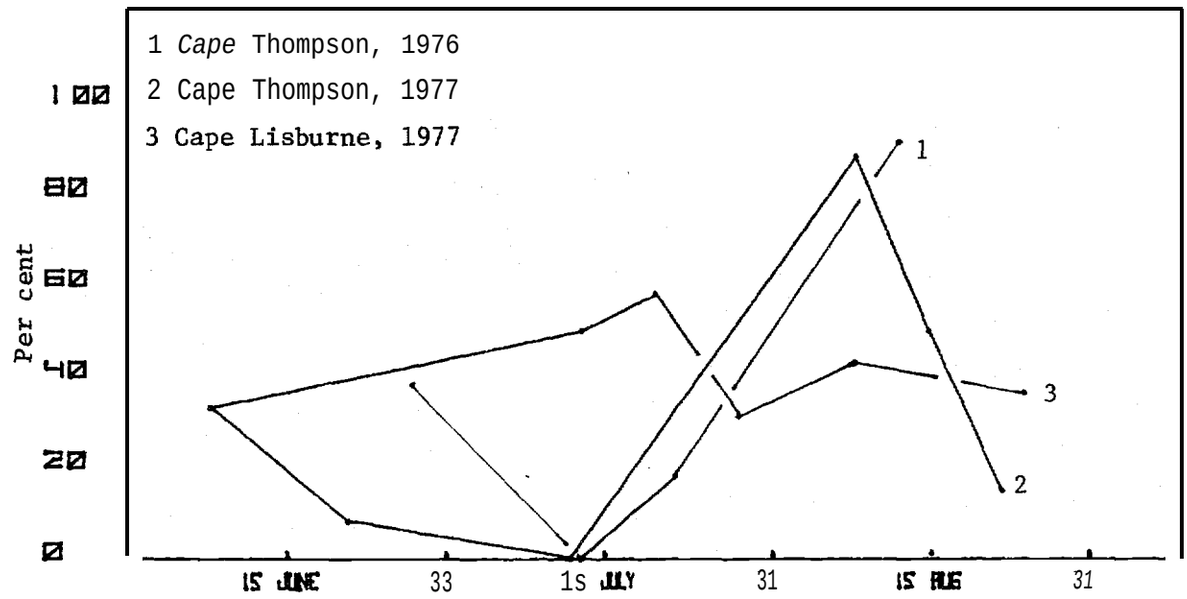
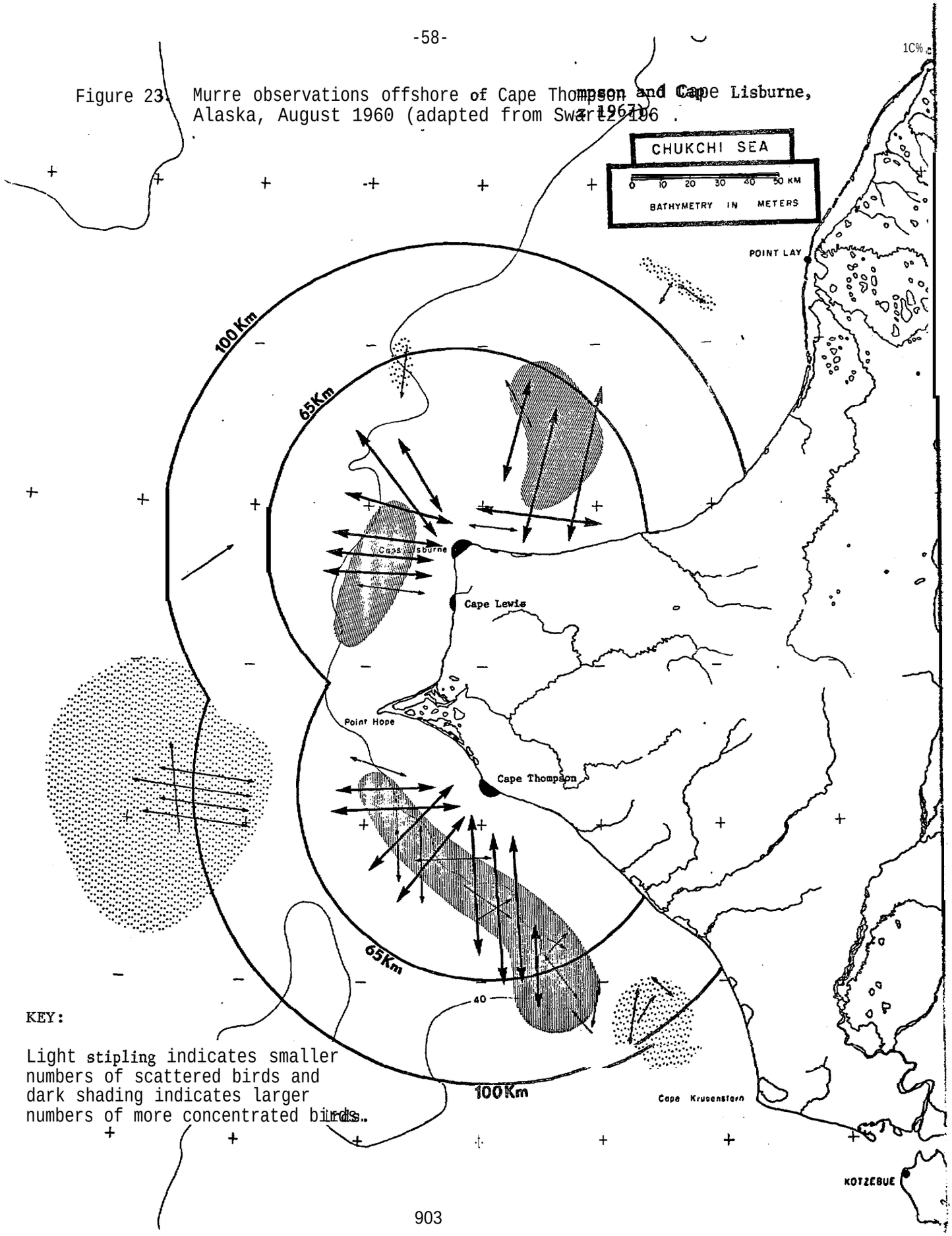


Figure 19. Seasonal utilization of Cottidae by Thick-billed Murres at Cape Thompson and Cape Lisburne.

Figure 23. Murre observations offshore of Cape Thompson and Cape Lisburne, Alaska, August 1960 (adapted from Swartz 1967).



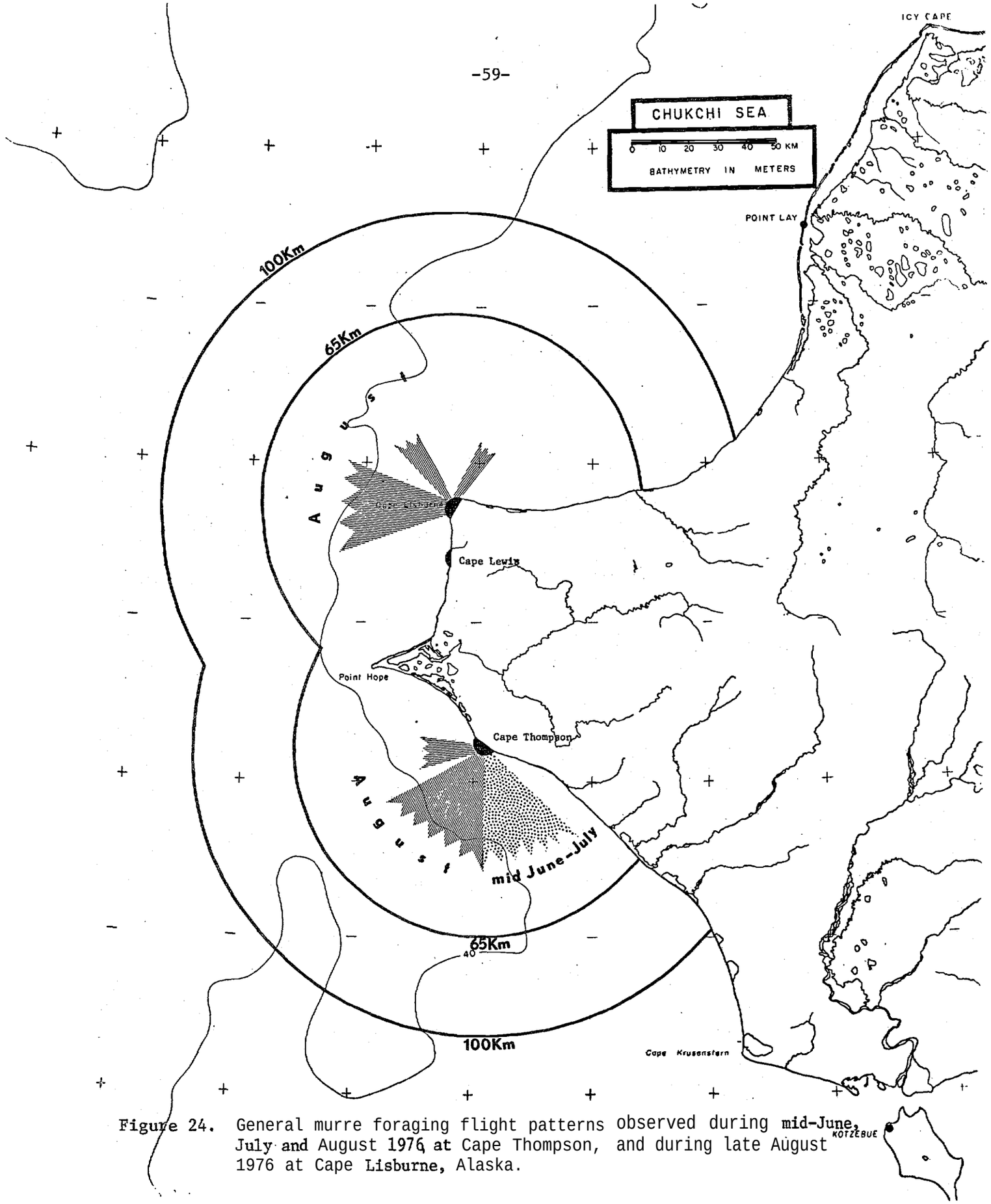
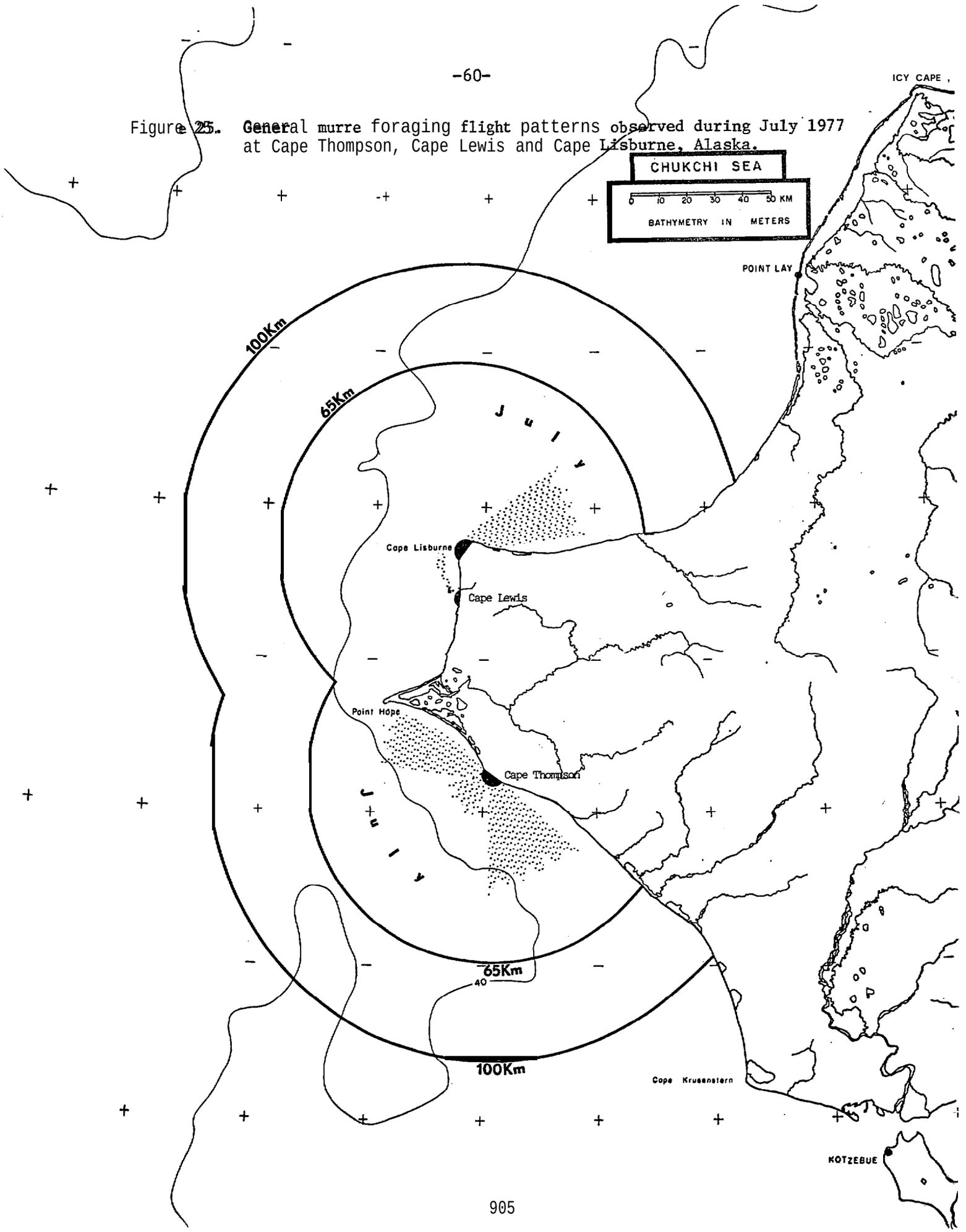


Figure 24. General murre foraging flight patterns observed during mid-June, July and August 1976 at Cape Thompson, and during late August 1976 at Cape Lisburne, Alaska.

Figure 25. General murre foraging flight patterns observed during July 1977 at Cape Thompson, Cape Lewis and Cape Lisburne, Alaska.



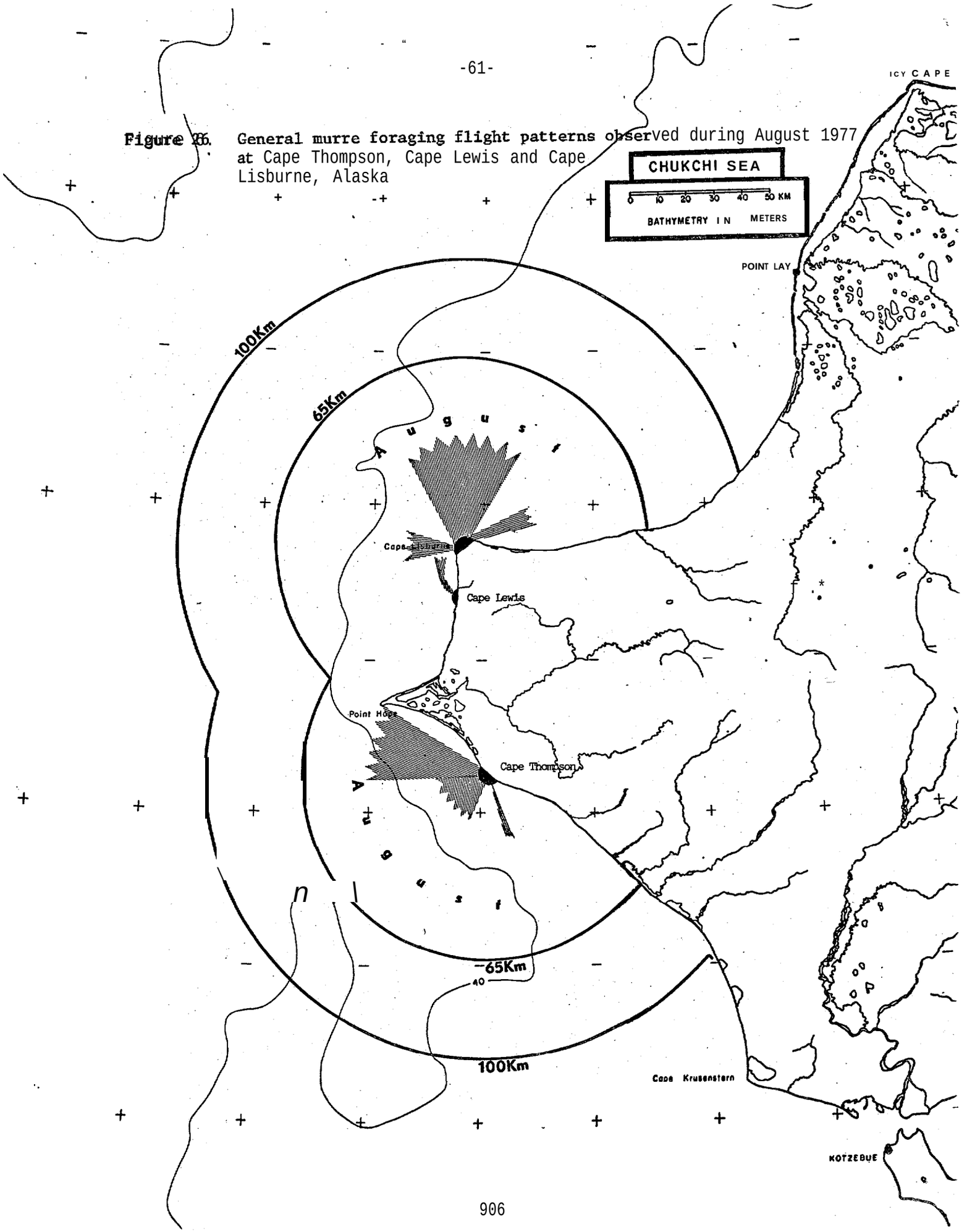


Figure 26. General murre foraging flight patterns observed during August 1977 at Cape Thompson, Cape Lewis and Cape Lisburne, Alaska

murre flocks flew out from the Cape Thompson colonies in a south and southwesterly direction and that many flocks returned to the colonies on the back-asimuths *of these courses. Other flocks followed flight tracks to and from the west and west-northwest* (Swartz *1967).*

In 1976 observations were made of the direction that murre flocks took when leaving and returning to the Cape Thompson colonies (see Figure 24). From 19 June to *about 1 August murres consistently followed a relatively well defined southerly flight pattern. Individuals and small groups (usually 2-10) departing the cliffs flew southeast and south-southeast. Much larger flocks (usually several 10's to a few hundred) returned from these same compass directions. On foggy days flocks closely paralleled the shoreline. As fog banks retreated offshore, flocks retreated with it, flying from about one to more than several kilometers offshore. On clear days flocks departed and returned to the area farther out to sea. Departing and returning flights of birds generally fell in* an *arc between about south-southeast and due south. Only relatively small numbers of murres appeared to depart to and return from the southwest and west, more directly offshore of the colonies, and no birds were observed flying to or from headings above 270°.*

During the first few days of August an interesting change became apparent. Few murres flew near the coastline. Instead, they departed to the south and southwest and returned from these same directions. By mid-August much larger numbers of murres also were returning from the west. This flight pattern persisted until our departure on 25 August; birds were still not observed to depart or return from the west-north quadrant.

Our observations of murre flight patterns to and from the colonies in 1977 were substantially different than those of 1976. During one visit on 21 June and on our arrival on 6 July, murres were observed following what appeared to be a flight pattern identical to the June-July 1976 pattern. It soon became apparent, however, that bird numbers returning from the southeast and south-southeast, though considerable, were not as large as those observed in 1976. Some murres appeared to be departing to and returning from the arc between south and west, while large numbers of murres, comparable to and perhaps even greater than those following the downcoast flight pattern, were returning to the colonies from the northwest and north-northwest.

By the end of the third week in July, murre flocks returning to the colonies from the southerly directions had declined markedly. By the first week of August as few as 1000 murres per hour were returning to the colonies from the southeast and south during the peak activity period. Collecting specimens downcoast of Cape Thompson became very difficult. The vast majority of all murres wereodeparting to and returning from upcoast, a compass direction of about 300 . Within a few days time virtually all murres followed this flight pattern and only a handful of individuals persisted in using the southerly flight pattern. By about 20 August, however, the upcoast flight pattern was shifting back to more directly offshore. Most departing and returning murres were using a more northwesterly and west-northwesterly flight pattern.

After about mid-August it also became apparent that greater and greater numbers of murres were feeding nearshore and just upcoast of and in front of the colonies. Prior to this virtually all murres were departing to and arriving from distances well beyond spotting scope range. Feeding activity near the colonies increased markedly on 21 August when many birds

were observed surfacing with Ammodytes. Even greater numbers of murres fed immediately in front of the colonies on 23 August, the day large schools of Ammodytes appeared along the bases of the sea cliffs. Feeding activity along the colonies was still apparent upon our 26 August departure date. Though apparently reduced in number, some flocks of murres still persisted in using the northwesterly flight pattern; however, more and more individuals appeared to be again departing to and returning from the west and southwest.

Several raft trips along the Cape Thompson coast provided some information on murre foraging distances during 1976 and 1977. Southeast of Ogotoruk Creek departing and returning murres were still evident at our maximum travel distance of about 24 kilometers. Between about 13-16 kilometers from the colony the southerly flight pattern angled farther offshore. In 1977 murres returning to the colonies from the northwest were coming from a *distance that certainly exceeded 16 kilometers.*

Swartz *(1967) found* murres *up* to at least 96 kilometers south of Cape Thompson, and up to about 150 kilometers west-northwest of the colonies (see Figure 23). The bulk of his murre observations occurred between about 25 and 70 kilometers offshore. Based on August 1960 shipboard observations Swartz reported that the principal foraging area utilized by the Cape Thompson murres appeared to lie primarily south of Point Hope. His data suggested that some feeding appeared to occur as far as about 64 kilometers from Cape Thompson, although most feeding activity appeared to take place within about 48 kilometers.

During aerial transects flown 19 June 1975 concentrations of seabirds, the majority of which were murres, were located about 70 kilometers south of Cape Thompson at about 67°30'N, 166°W (Harrison pers. comm.). Harrison also reported fewer but substantial numbers of murres at the same location on 21 August 1976. Similar concentrations of murres were found in this same general location during early September 1976 by shipboard observers (Gould pers. comm.). Three of four murres collected on 20-22 August 1960 from this same general locale (67°53'N, 166°09'W and 67°38'N, 165°45'W) showed evidence of breeding (Swartz 1967).

August 1960 shipboard observations in the vicinity of Cape Lisburne indicated that many murres departed to and returned from the west; others followed a northwest-southeast line and smaller numbers, observed to the northeast of the colony, followed a north-northeast, south-southwest line (Swartz 1967).

During our reconnaissance of the Cape Lisburne colony between 25 August and 1 September 1976 murres were noted predominantly departing to and returning from the north-northwest to west compass arc while smaller numbers returned from the northeast. Upon our arrival in 1977 virtually all Cape Lisburne murres were departing to and returning from the east-northeast and northeast. Murres were never observed flying to or returning from any direction in the 180°-360° arc.

On foggy days large numbers of murres followed the northern shoreline, while on clear days the southern edge of the flight pattern was often a few kilometers offshore. Observations up to about 50 kilometers east suggested that between about 16 and 24 kilometers from the colony the flight pattern curved farther offshore to the north and northeast. Although some flocks of murres were still following the shoreline from the east, many flocks of murres were intersecting the shoreline from farther offshore. This flight pattern was constant throughout July.

During the last few days of July and the first few days of August it was apparent that a change was in progress. Large numbers of murres became more common on the water off of the west side of the colony. Somewhat fewer murres followed the east-northeast and northeast flight pattern, while larger numbers departed to and returned from the region between north-northeast and north-northwest. During early August some murres began returning from a more northwesterly direction and a smaller proportion still persisted in following the northeasterly flight pattern. After a violent storm on 8-9 August when many Ammodytes washed up on the northfacing beach, tremendous feeding activity was concentrated in the coastal waters all along the colony although some murres still followed the early August flight pattern. The number of murres feeding away from the colonies continued to decline until our 4 September departure.

An attempt was made to gain perspective on how far murres were traveling eastward of the colony in 1977. A reconnaissance trip about 50 kilometers to the east revealed that flocks of returning murres were still evidently following the coastline from the east within sight of the beach. Swartz (1967) found murres up to about 50 kilometers eastward of Cape Lisburne and up to about 120 kilometers northeastward and north. Most of his murre observations to the northeast, north and west of the colony occurred within about 50 kilometers.

Some observations were obtained in 1977 that suggest murres breeding at Cape Lewis, about 18.5 kilometers south of Cape Lisburne, forage in the same areas that Cape Lisburne murres utilize. During July and early August, small flocks of murres were occasionally observed flying south, by-passing the Kay Creek vicinity of the colony. These small flocks were often 1-2 kilometers offshore.

On 27 July a reconnaissance trip was made as far south as Cape Dyer, 7 kilometers beyond Cape Lewis. Small flocks of murres were observed carrying fish past the southern terminus of the Cape Lisburne colony. Throughout that day southbound flocks were observed along the coast between Cape Lisburne and Cape Lewis, where they landed. During several hours of observation murres were observed only once departing to or returning from the west or south. Between Cape Lewis and Cape Dyer one small flock of northbound murres (approximately 10 individuals) was encountered. If Cape Lewis murres were flying distances north and east of Cape Lisburne comparable to those of murres nesting at this more northern colony, they may have foraged at least 70-90 kilometers away from their nesting site.

Growth rates

Thirty-one Thick-billed Murre chicks at Cape Lisburne were weighed periodically during intervals of 6 to 21 days. Murre chicks do not exhibit a regular increment of growth throughout their nest life, so deriving growth rate averages is difficult. We obtained a mean growth rate for the 31 chicks of 6.1±2.3 grams per day by dividing the change in weight between the lowest observed and the highest observed by the number of days between those observations.

The greatest weight obtained by any chick we weighed was 210 grams and the average of five 21-day old chicks was 170±36 grams. The maximum weight achieved by murre chicks characteristically occurs a few days before they leave the cliffs, a phenomenon described by Tuck (1960) and

Belopolskii *(1957). The weight loss is attributed to rapid growth of feathers immediately preceding departure. This pattern was also evident among* murre *chicks at Cape* Lisburne.

Mortality

Egg collecting by local people from Point Hope and Kivalina occurred at Cape Thompson during 1977. At least eight egging parties visited the cliffs during the period 6-15 July. We doubt that more than 1500 to 2000 eggs were collected in 1977 which agrees with the estimate of Swartz (1966) for 1960. To our knowledge, no eggs were collected in 1976. Because murres will re-lay after the loss of the first egg and because other mortality factors such as predation of eggs by gulls and ravens are certainly of much greater magnitude, we believe that current losses to local residents are of little significance to the murre population.

Eggs were also collected from Cape Lisburne by people from Point Hope. All collecting occurred before we arrived at the site and we do not know the numbers of eggs taken. According to one resident of Point Hope, four parties visited Cape Lisburne and probably gathered about the same number of eggs that were taken at Cape, Thompson.

The greatest loss of eggs at Cape Thompson resulted from gull and raven depredation. We cannot estimate the number of eggs taken by these birds but murre eggs and chicks probably constitute the bulk of the diets of both species during the majority of the summer. The slopes above the cliffs are littered with broken shells of eggs which were carried there and eaten by gulls and ravens.

Gulls and ravens also were responsible for taking a large number of eggs and chicks at Cape Lisburne. Perhaps of greater significance to the murre population, however, . were losses to a resident grizzly bear. The bear was about three years old and had an uncanny ability to navigate the most precipitous of faces on the cliffs in his search for eggs and chicks. On one occasion his position was so precarious that we dropped anchor and simply waited for him to fall. After some 45 minutes he was still maneuvering about the cliffs, and in the process undoubtedly ate several hundred eggs.

Not only did this bear prove to be a hindrance to the success of the murre reproductive effort this season but it also proved to be a hindrance to our own research efforts. Sixteen of 39 chicks we were weighing were eaten. Approximately 50 of 60 eggs on one study plot we were monitoring were eaten. Other bears, which also frequented the area, may have taken eggs and chicks as well. A grizzly bear also ate a few murre eggs and chicks in late august at Colony 4, Cape Thompson; however, this bear did not appear to rely on this food source as did the bear at Cape Lisburne.

The winds discussed earlier in the report also contributed to adult murre mortality. The winds at Cape Thompson and Cape Lisburne are probably the single most important mortality factor affecting adult birds. Murres were regularly seen along the beaches in front of the cliffs wounded, usually with broken wings and/or broken legs. Both years many birds were also found dead at the base of the cliffs after having apparently smashed headlong into the rock.

Rock falls at Cape Thompson also kill many adult murres and kittiwakes during the breeding season. A nearly constant shower of small to medium sized rocks falls along many sections of the cliffs. Some of the rocks occasionally strike birds and either kill them outright or mortally

wound them. Large rock falls are infrequent but when they occur many birds and large areas of nesting habitat can be affected. One large rock fall at Colony 5 spilled over a section of cliff where murres were nesting. From the raft we could see at least six dead murres on top of the rock pile at the bottom of the cliff; however, many more birds were certainly buried beneath the large mass of rubble.

Occasionally entire sections of a cliff face will peel off and fall. At least twelve adult kittiwakes and one chick were *killed when a small section of cliff at Colony 3 broke off. At Colony 2 a portion of cliff fell away and at least four adult murres, three adult kittiwakes and an adult Horned Puffin were killed.*

B. Black-legged Kittiwakes

Census

The methods used to estimate the number of kittiwakes breeding at Cape Thompson in 1960 and 1961 were different than those used in 1976 and 1977. In 1960 and 1961 nest sites were counted to arrive at a total breeding population. Because so few birds were nesting in 1976, we counted the total birds on the cliffs that year. We counted total birds again in 1977 so that comparisons with 1976 could be made more easily. The summaries of all counts made at Cape Thompson are presented in Table 25 and the individual plot counts for 1977 are presented in Tables 26-29.

The number of birds counted at Cape Thompson *in 1977 was 10,228 which was very close to the number obtained in 1976, 10,540. Both of these values are somewhat lower than the number of nests counted by Swartz in 1960 and* 1961. *Most birds counted in 1976 and 1977 were sitting singly on what appeared to be nest sites, although all of the sites were obviously not successful. Pairs were occasionally present on sites, however, and the totals for our counts are certainly higher than the number of nests which were being defended. The size of the difference between the 'breeding populations' in 1960-61 and 1976-77, therefore, may be larger than our counts suggest.*

Table 25. Black-legged Kittiwake census summary, Cape Thompson.[1]

	Colony					
Year	*1*	2	3	4	5	Total
1960	0	5253	2950	3132	3180	14,515
1961	0	4914[2]	3533[2]	3131	3214[2]	14,792
1976	0	3373	3086	1649	2432	10,540
1977	*0*	*3445*	*2657*	*2459*	*1667*	*10,228*

[1] *number for 1960 and 1961 are total nests; numbers for 1976 and 1977 are total birds. Numbers reported* here for 1960 and 1961 were obtained from unpublished field notes and summary sheets. Numbers reported in Swartz (1966) were derived by multiplying these figures x 2 and rouding off; this step was inadvertently omitted in the case of the published Colony 5 total.

[2] estimates based on partial counts

Table 30 presents results of the kittiwake census at Cape Lisburne for 1977. The number of birds on each of 57 plots were counted while only the total number of sites on the remaining 18 plots were counted. A site was defined as any place on the cliff where a kittiwake was present and which showed signs of repeated use. In the majority of cases, a nest or at least evidence of nest construction was visible. The total number of birds counted plus the number of sites where only sites were counted equals 14,478.

We counted the number of birds and the number of sites on 38 plots. The mean number of birds per site was 1.05±0.05. By using this calculation and by making the assumption that each site represented a nesting attempt by a pair of birds, we were able to derive an estimate of the number of "breeding" birds present-at Cape Lisburne in 1977.

We counted 3798 sites on the 18 plots where only sites were counted. Based on the observed ratio of 1.05 birds per nesting site we estimate that about 3988 birds were present on those plots at the time they were counted. By adding that figure to the number of birds which were counted (10,680), we estimate that about 14,668 birds were present on the cliffs at the time of the census.

As with murres, many kittiwakes were away from the colony during the census. This figure, therefore, is a *minimum estimate of the size of the kittiwake population at Cape Lisburne. If the ratio of 1.05 birds per site implies that up to 47% of all individuals comprising a pair were away from the cliffs, the 'breeding' population could exceed 28,000 birds.*

Large number of kittiwakes were seen regularly at creek mouths to the south of Cape Lisburne as well as along the lagoons to the east of the cape. Flocks of 175, 913, 107 and 432 kittiwakes were observed in a distance of about 14 kilometers between Cape Lisburne and Noyalik Peak on 13 July. Five birds were collected from a flock of approximately 200 birds at the mouth of Alkalugen Creek on 14 July. All five birds were females, 4 of which had very little or no broodpatch development. These 5 females weighed an average of 400±16 grams and had an average whole body fat content of 27?4.9%. Four females were collected from feeding groups in front of the cliffs on 12 and 13 July. The average weight of these birds was 424±33 grams and the whole body fat content was 32±3.9%. Three of the four birds had well developed brood patches. These observations suggest that non-breeding females remain in large groups and tend to "hang out" in the vicinity of the nesting colonies during the summer. If all of the kittiwakes in these large flocks were non-breeding females, the size of this cohort relative to the size of the breeding population was substantial.

Activity patterns

One *24-hour activity count was made at Cape Thompson on 25-26 July. The curve generated by these counts is illustrated in Figure 27. Maximum attendance on the cliffs by kittiwakes occurred during early morning between 0500 and 0800 hours. The low occurred approximately 12 hours later when about 60% of the morning maximum was counted. Similar counts at Cape Lisburne were not made.*

Phenology

The timing of events in the breeding cycle of kittiwakes at Cape Thompson were consistent with dates reported by Swartz during 1959-1961, but

Table 26. Black-legged Kittiwake census, Colony 2; Cape Thompson, 1977.

17 July				
Plot	Time	Observer F	Observer G	$\bar{x}$
A	2240	0	0	0
B		0	0	0
C-F		263	275	269
G-J		473	478	476
K-N		713	705	709
O-R		364	330	347
S,T		307	273	290
u		496	506	501
V,W		377	369	373
X,Y		63	43	53
Z,AA		121	126	124
BB,CC	0130	87	82	85
DD- FF	1900	191	197	194
GG-II	1915	24	24	24
Total		3,479	3,408	3,445

Table 27. Black-legged Kittiwake census, Colony 3; Cape Thompson, 1977.

24 July and 3 August				
Plot	Time	Observer F	Observer G	$\bar{x}$
A	2105	0	0	0
B		4 "	4	4
c		36	34	35
D-F		73	73	73
H		331	325	328
G,I-L		1591	1657	1624
M,N	2200	207	232	220
O		122	103	113
P		141	146	144
Q	2230	83	76	80
R,S		36	36	36
Total		2,624	2,686	2,657

Table 28. Black-legged Kittiwake census, Colony 4; Cape Thompson, 1977.

Plot	Time	18 July		
		Observer F	Observer G	$\bar{x}$
A,B	2200	410	449	430
C		287	290	289
D,E		423	385	404
F,G		435	406	421
H		283	284	284
I		97	107	102
J-L, O		309	277	293
M,N,P-R	0130	241	234	238
Total		2485	2432	2459

Table 29. Black-legged Kittiwakes census, Colony 5; Cape Thompson, 1977.

		19 July		
Plot	Time	Observer F	Observer G	$\bar{x}$
A	0130	46	51	49
B	0130	121	115	118
c	0130	114	118	116
D	**0130**	**46**	**48**	**47**
E	0130	467	436	452
F	0330	369	315	342
G	1700	311	359	335
H	1700	182	183	183
I	1700	21	22	22
J	1800	0	0	0
K	1800	0	0	0
L	1820	2	3	3
Total		1,679	1,650	1,667

Table 30. Black-legged Kittiwake census; Cape Lisburne, 1977.

Plot	Date	Time	Total Birds	Total Sites
1	7 Aug	1730	291	285
2		1800	52	46
3			0	0
4			0	0
5			0	0
6		1815	85	81
7	12 Aug	1800	39	38
8		1810	34	32
9		1820	155	150
10		1830	169	163
11		1850	114	112
12		1900	75	73
13		1910	269	
14		1920	182	170
15	14 Aug	1900	348	
16	27 Aug		58	
17			649	
18			3	3
19			382	328
20			786	705
21			115	104
22			219	197
23			88	80
24			172	153
25			54	48
26			265	235
27	13 Aug	2120	0	
28		2105	228	
29		2100	104	104
30		2050	126	126
31	27 Aug			846
32				0
33				173
34				239
35				67
36				359
37	13 Aug	2045	4	
38		2040	0	
39		2035	114	
40		2030	168	
41	27 Aug			55
42				95
43				52
44				16
45				39
46				208
47				98

Plot	Date	Time	Total Birds	Total Sites
48				288
49				393
50				512
51				184
52	16 Aug	2030	243	243
53		2020	133	133
54		2010	135	135
55		1950	640	640
56		1935	73	73
57		1920	67	
58		1910	130	
59		1840	146	
60	15 Aug	1930	72	
61		1915	205	
62		1900	293	
63		1830	878	
64		1800	571	571
65	16 Aug	2115	247	247
66		2110	50	50
67		2105	141	
68	13 Aug	1930	182	176
69	16 Aug	2130	28	
70	11 Aug	1500	296	291
71		1440	177	172
72		1420	274	259
73		1400	349	337
74	27 Aug			174
75			0	0

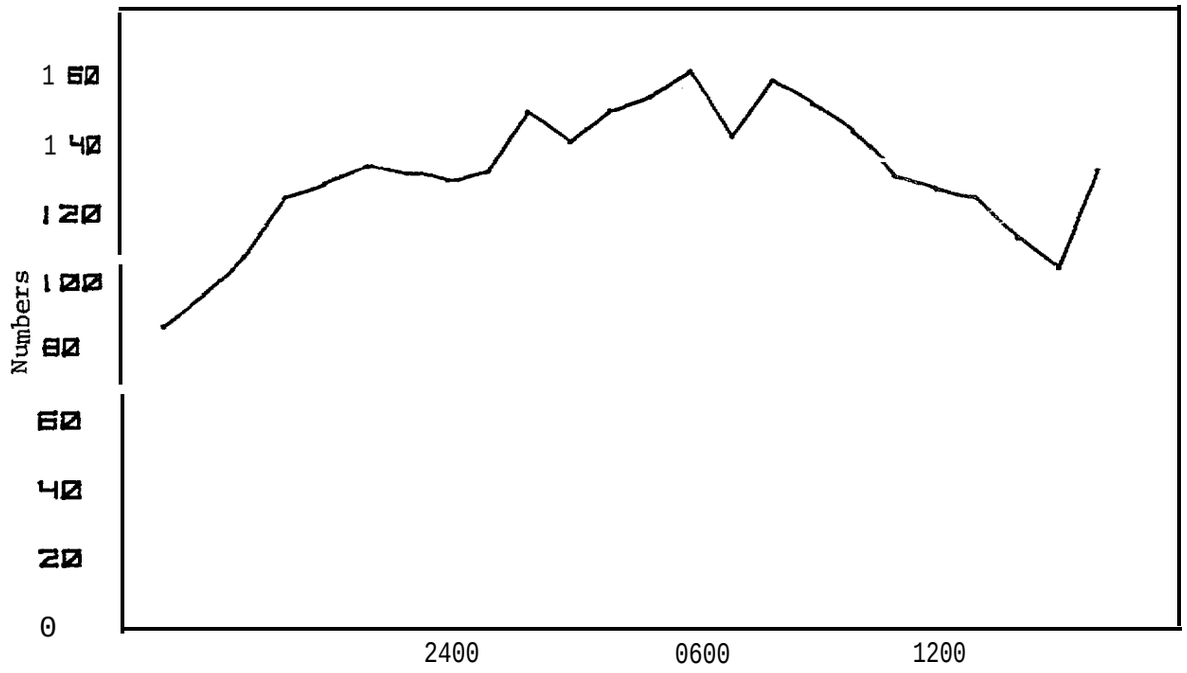


Figure 27. Diurnal activity of Black-legged Kittiwakes at Cape Thompson.

were somewhat earlier than 1976. These data are presented in Table 31. The date of first hatching in 1977 appears to be earlier than dates for hatching in other years. However, if first hatching dates for 1959, 1960 and 1961 were calculated on the basis of a 44-day nestling period (see Swartz 1966) and the date of first fledging, as was done in 1977, these hatching dates would be earlier than those reported in Table 31. Hatching dates in 1977 appear to have been much earlier than in 1976, as they were during 1959-1961.

Table 31. Phenology of nesting activities of Black-legged Kittiwakes at Cape Thompson.

Year	First building	First egg	First hatching	First fledging
1959	not observed	22 June	20 July	30 August
1960	13 June	21 June	17 July	20 August
1961	18 June	25 June	22 July	27 August
1976	not observed	4 July	9 August	not observed
1977	not observed	not observed	10 July[1]	23 August

[1] calculated on the basis of a 44-day nestling period and the date of first fledging

Because the majority of kittiwake eggs had been laid by the time we arrived at the site in 1977, we have few observations of laying dates. Laying dates calculated on the basis of hatching dates (28-day incubation period, see Swartz 1966) suggest that the majority of eggs were laid about 1 July and increased to a peak about 12 July.

Eggs began to hatch towards the end of July, and most eggs had hatched by 9 August. The peak hatch probably occurred during the interval 1-5 August. These data are listed in Table 32. At least one egg hatched as late as 21 August. The first fully fledged young was observed on 23 August . If 44 days is used as the mean nestling period, then this chick hatched on about 10 July from an egg which had been laid as early as about 12 June. Several other young were within a few days of their first flight by 23 August and had virtually no down left on them. Most of the chicks, however, did not make their first flight until mid-September, and some young may have fledged as late as early October.

Kittiwakes laid later at Cape Lisburne in 1977 than they did at Cape Thompson. Laying dates calculated from hatching dates indicate that laying commenced as early as 29 June, however, most laying probably occurred during the 8-23 July interval. Hatching dates of eggs in monitored nests (see Table 32) suggest that the reproductive season at Cape Lisburne was about a week to "10 days later than at Cape Thompson. The first chick may have fledged as early as 8 September, however, most chicks probably did not make their first flight until mid-September. A few young may have fledged as late as mid-October.

Table 32. Hatching dates of Black-legged Kittiwakes, 1977.

	Cape Thompson	Cape Lisburne
Before 29 July	2	
29-30 July	2	
30 July-1 August	8	
1-5 August	25	1
5-9 August	9	4
After 9 August	3	
9-12 August		3
12-15 August		5
15-20 August		5
20-26 August		1

Food habits

The food habits of kittiwakes at Cape Thompson as determined from stomach contents analyses for 1960, 1976 and 1977 are presented in Table 33. The data obtained from birds collected in 1977 are similar to those from 1960 but are quite different from 1976.

The relative frequencies of fish identified in 1960 and 1977 were nearly the same and were considerably higher than in 1976. By contrast, the frequency of invertebrates identified in 1960 and 1977 also were about the same but were much lower than the frequency of invertebrates in 1976.

Cod were important to kittiwakes and no major differences were seen in the utilization of this fish between any years. The only exception to this may be in the absence of Saffron Cod in 1960. Notable differences do exist, however, in the utilization of other fish species. Sand Launce and Capelin were not identified in the food from 1976, however, both were utilized to some extent in 1960 and 1977, especially Sand Launce.

The importance of Sand Launce to the kittiwake population at Cape Thompson in 1977 is not apparent from Table 33. When the food habits of kittiwakes are seen on a seasonal basis the significance of this food item is obvious. These seasonal data are presented in Table 34. Although no Sand Launce were identified from kittiwakes collected in July, by the end of August they occurred in all of the stomachs. Cod were important in early summer and progressively decreased through the end of August, while Capelin were found in only one sample, the collection of 6-11 August. Besides cod, polychaetes may be important early season food to kittiwakes.

The food items identified from the stomach contents of kittiwakes collected at Cape Lisburne in 1977 also are presented in Table 33. The relation of fish utilization to invertebrate utilization was about the

Table 33. Food of Black-legged Kittiwakes at Cape Thompson and Cape Lisburne, Alaska. Percent occurrence of food items refers only to those stomachs containing food; values in parentheses refer to the total sample.

	Cape Thompson						Cape Lisburne	
	1960		1976		1977		1977	
	n	%	n	%	n	%	n	%
Total examined	115		22		52		39	
Number empty	23	(20)	7	(32)	3	(6)	2	(5)
Frequency of invertebrates	23	25	8	53	11	22	13	35
Frequency of fish	84	91.3	10	67	48	98	34	92
FISH:								
Gadidae	1	1.1			1	2		
Boreogadus saida	50	54.3	5	33	29	59	18	49
Eleginus gracilis			5	33	23	47	3	8
Cottidae								
Myoxocephalus quadricornis	2	2.2						
Pungitius pungitius	1	1.1	1	7				
Ammodytes hexapterus	19	20.6			11	22	17	46
Ammodytes sp.	8	8.7						
Mallotus villosus	2	2.2			4	8		
Liparus sp.							1	3
Pleuronectidae			1	7				
Unidentifiable	4	4.3			3	6	2	5
INVERTEBRATES :								
Oligochaeta							1	3
Polychaeta	5	5.4	1	7			2	5
Nereis sp.					1	2	4	11
Mollusca					2	4	2	5
Pteropoda					1	2	2	5
Limacina helicina							1	3
Gastropoda			2	13				
Trochidae			1	7				
Pelecypoda					1	2	1	3
Arthropoda					1	2	1	3
Calanoida					3	6		
Onacaea					1	2		
Isopoda	2	2.2	1	7				
Gammaridae, sp. 3	3	3.3						
Cumacea	1	1.1						

	Cape Thompson						Cape Lisburne	
	1960		1976		1977		1977	
	n	%	n	%	n	%	n	%
Decapoda								
Pandalus sp.			1	7				
P. goniurus	1	1.1	1	7	1	2		
P. jordani					1	2		
P. borealis	1	1.1						
Eualus gaimardi	1	1.1	1	7				
Hyas coractatus	1	1.1						
Unidentifiable			2	14				
Coleoptera			1	7				
Hymenopteran			1	7				
Mallophaga	1	1.1						
Siphonaptera	2	2.2						
Insect larvae	1	1.1						
Unidentifiable invertebrates	12	13						
MISCELLANEOUS								
Plant matter	10	10.9						
Algae	1	1.1						
Pebbles	8	8.7	1	7	4	8	10	27

Table 34. Percent occurrence of major food groups of Black-legged Kittiwakes, 1977.

	Cape Thompson				Cape Lisburne	
	July 12-14	July 20	Aug. 6-11	Aug. 17-23	July 12	Aug. 1
Gadidae	100	84	14	0	88	0
Cottidae					12	8
Ammodytes	0	0	57	100	29	77
Mallotus	0	0	57	0	0	0
Polychaeta	7	0	0	0	29	0
n	15	19	7	7	17	13

same as at Cape Thompson. Arctic Cod occurred in about equal frequencies at Cape Lisburne and at Cape Thompson. The apparent utilization of Saffron Cod at Cape Lisburne, however, was much lower than at Cape Thompson. No Capelin were found in any kittiwakes from Cape Lisburne compared to an 8% occurrence in birds collected at Cape Thompson. Sand Launce were found in nearly twice as many stomachs from birds collected at Cape Lisburne as at Cape Thompson. We believe that this apparent difference is an artifact which results from two factors: more kittiwakes were collected early in the summer at Cape Thompson before Sand Launce had arrived, and the Sand Launce arrived earlier at Cape Lisburne.

The only major difference in invertebrate prey between the two colonies in 1977 occurred in the relatively high utilization of polychaetes (Nereis) at Cape Lisburne.

Some indication of seasonal differences in food habits at Cape Lisburne are seen from the data presented in Table 34. All of the cod and all of the polychaetes occurred in the 12 July sample while the majority of Sand Launce occurred in the 1 August sample. Utilization of cod was about equal between the two dates. These data are similar to those from Cape Thompson and demonstrate pronounced seasonal changes in food habits at both colonies.

Annual differences in the relative utilization of fish and invertebrates by kittiwakes can be seen in Figure 28. Fish appear to have been more important than invertebrates to kittiwakes at Cape Thompson in 1960 and 1977, and at Cape Lisburne in 1977. At Cape Thompson in 1976 fish and invertebrates were recorded in about equal frequencies. The yearly differences observed in the fish: invertebrate ratios are similar to those of murres (see Figures 13 and 14).

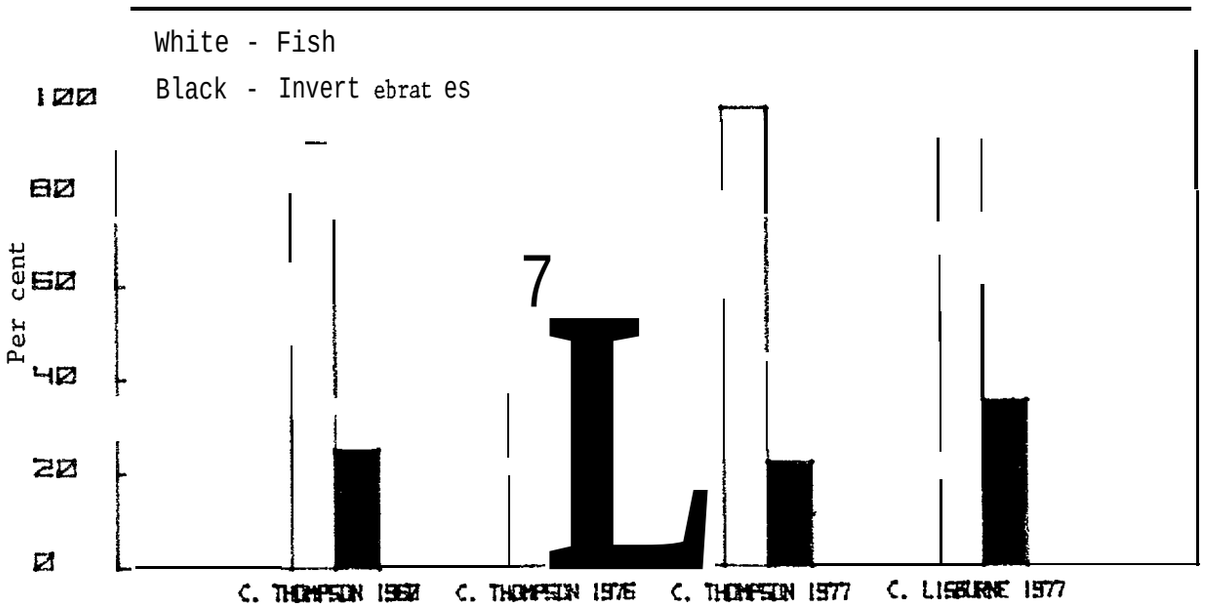


Figure 28. Relative occurrence of fish and invertebrates in stomach contents *of* Black-legged Kittiwakes collected at Cape Thompson and Cape Lisburne.

Foraging patterns

We are not certain how far Cape Thompson kittiwakes forage from the colonies. It is probably a shorter distance than that flown by murres. Although Swartz (1967) recorded kittiwakes as far as about 220 kilometers from the nearest colony, it is likely that many of these were nonbreeders. Most of the August 1960 kittiwake observations near Cape Thompson occurred within 16 kilometers of shore (Swartz 1967); beyond this only scattered, relatively small numbers were seen.

In 1976 kittiwakes were observed feeding offshore of the colonies and flying to the southeast (downcast). Departing kittiwakes usually followed the surfline, while returning flocks, paralleling the beach, were usually between about 100 meters to one kilometer offshore. Kittiwakes were never observed flying upcoast toward Point Hope from the colonies that year.

On several raft trips during early August 1976 up to 24 kilometers downcoast of the Cape Thompson colonies we still encountered a few small flocks of traveling or resting kittiwakes. Beyond about 13 kilometers southeast of Ogotoruk Creek, however, kittiwakes were scarce. During August flocks of kittiwakes traveling downcoast past Ogotoruk Creek became fewer in number. It was more common to see them rafting or flying about offshore in front of the colonies. Only three feeding melees were observed all summer. All occurred directly offshore of the Cape Thompson cliffs.

Flocks of kittiwakes were observed again in 1977 feeding among ice floes off of the colonies and nearby beaches. Small feeding melees were commonly observed along the colonies. A constant progression of birds also was observed flying to and from the southeast along the coast, as observed in 1976. At least comparable, if not larger, numbers, however, were flying to and from the north-northwest along the coastline between Colony 5 and Point Hope.

The number of kittiwakes flying to the southeast of the colonies had declined by the first week of August. Instead, the birds tended to fly more directly offshore. By about 10 August larger feeding melees off of the colonies or within several kilometers upcoast of them had become more common, and by 15 August the majority of all kittiwakes followed the upcoast flight pattern.

On 23 August large schools of Ammodytes moved southward along the Cape Thompson coastline. Many large feeding melees of several hundred up to about 1000 kittiwakes followed this movement toward Colony 5, although flocks of kittiwakes continued to travel at least several kilometers upcoast. By 25 August large numbers of kittiwakes again followed a southeast flight pattern. On 26 August, our departure date, our pilot reported several large (approximately 150 individuals per group) melees along the coast as far southeast as about 50 kilometers. Flying the coast a few hours later we observed small flocks of kittiwakes scattered as far as the report indicated. It was not known if kittiwakes still traveled upcoast toward Point Hope; however, the number of birds observed near Colonies 1, 2 and 3 and to the southeast toward Kivalina suggested that substantial numbers probably were still feeding to the north of Colony 5. on that date.

Upon our arrival at Cape Lisaburne on 6 July 1977 kittiwakes were observed feeding among the ice floes in front of and to the north and east of the colony. Considerable foraging occurred for up to at least several

kilometers offshore along the north-facing beach and for several kilometers to the east. Small schools of B. saida were discovered to be 'hiding' under the ice floes and kittiwakes were observed catching them. Kittiwakes that appeared to travel greater distances to feed departed to and returned from the east and east-north east.

Ice cover along the north coast was rapidly diminishing by about 23 July and more flocks of outward bound kittiwakes flew east along the shoreline and returned from some distant point by the same route. By 1 August virtually all kittiwakes from the Cape Lisburne colony apparently followed this flight pattern. On 2 August we was discovered that large numbers of kittiwakes could be found traveling to and returning from as far east as the Corwin Creek area, about 45 kilometers from the nearest nesting pairs. Beyond that point few kittiwakes were observed. Small feeding melees were observed between Isuk Creek and Corwin Creek. High soaring flocks of kittiwakes were continually drifting in from farther offshore to join birds returning to the Cape along the coast. Returning kittiwakes were gorged with Ammodytes.

After 5 August more feeding activity was observed offshore of the colonies. On 8-9 August a violent storm carried Ammodytes up on the north-facing beach. Between 10 August and 5 September huge feeding melees of kittiwakes were common all along the cliffs in the immediate vicinity of the colony. This situation persisted through our departure in early September.

Reproductive success

The productivity of kittiwakes at Cape Thompson in 1977 was considerably better than in 1976, although it was still well below that reported for this colony by Swartz for 1960 and 1961.

Most of the sites which were defended by kittiwakes in 1977 showed evidence of nest construction. If the presence of a site containing nesting material (mud and/or grass) is assumed to represent a nesting attempt by a pair of kittiwakes, then we estimate that approximately half of the attempts at Cape Thompson were successful in 1977.

By the end of July, we had been able to determine the contents of 157 kittiwake nests, 44(28%) of which were empty. We monitored the contents of 73 kittiwake nests through 20 August, during which time 18 nests (25%} failed. If 25% of the 113 (157 minus 44) nests which were active in late July failed, then a total of 72 (44 plus 28) or 46% would have been empty by 20 August. On 23 August, 238 nests were examined at Colony 4. One nest contained one egg, one nest contained two eggs, 128 nests contained one chick each, 4 nests contained 2 chicks each and 104 nests (44%) were empty.

The 113 active nests which we examined in late July contained a total of 136 eggs for an average clutch size of 1.20 eggs per nest. Eighty-four eggs were laid in the 73 nests (1.15 eggs per nest) which we were able to monitor, 8 of which were lost during incubation for a hatching success of 90%. Of the 76 chicks which hatched, at least 22 died before fledging, yielding a maximum possible fledging success (chick fledged/chick hatched) of 71% and a maximum possible breeding success (chick fledged/egg laid) of 64%. These data are compared in Table 35 to similar data reported by Swartz (1966) for Cape Thompson in 1960 and 1961, and for data obtained at Cape Lisburne in 1977.

The hatching success of eggs at Cape Thompson in 1977 was higher

than in either 1960 or 1961. A greater percentage of the chicks died before fledging, however, and the overall breeding success may have been about equal to that in 1960 and somewhat higher than in 1961. Of the 73 nests which we monitored, 13 had two-egg clutches at the end of July, but only two of these nests contained two chicks by 20 August. Although only one egg of each of two two-egg clutches was-lost before hatching, seven nests lost one each of two chicks after hatching and two nests lost both chicks. The losses tended to occur while the chicks were less than ten days old and the younger of the two chicks was generally the one which died.

Table 35. Reproductive success of Black-legged Kittiwakes.

	Cape Thompson			Cape Lisburne
	1960[1]	1961[1]	1977	1977
No. nests of known clutch size	*60*	*29*	*73*	*19*
Average clutch size	*1.92*	*1.98*	*1.15-1.20*	*1.11-1.16*
Hatching success	.75	.69	.90 "	.95
Fledging success	.86	.60	.71	.89
Breeding success (chicks fledged/eggs laid)	.65	.41	.64	.85

[1]data from Swartz (1966)

Between 23 July and 6 August we examined 146 kittiwake nests in six different locations at Cape Lisburne. Not all nests were well constructed but all showed evidence of recent attention. Of the total, 61 (42%) were empty while the remainder contained either eggs or chicks. The ratio of active to inactive nests was similar to that observed at Cape Thompson on 23 August.

The average clutch size of kittiwakes at Cape Lisburne *in 1977, 1.11-1.16 eggs per active nest, was slightly lower than at Cape Thompson.* The hatching *success (95%), however, and possible fledging success of 89% were both higher than values for the same ratios in any year at Cape Thompson. The result was that the breeding success may have been as high as .85 chicks per egg laid. Admittedly this may be higher than actual; no young had fledged by the time we left and many of the chicks were not more than half grown. There was no* indication that the food source was diminish*ing however, and unless it did* drop after we left, or if severe weather *occurred, we have no reason to* believe that productivity would have been *lower.*

Growth rates

The majority of the kittiwake nests at both sites were inaccessible to us. At Cape Thompson we were able to weigh nine chicks at intervals during ten days, and five of those chicks during a period of 14 days. The

average growth rate of the nine chicks during the ten-day interval was 14.2±3.4 grams per day. This growth rate continued during at least the next four days; the five chicks which were weighed at intervals for 14 days exhibited a growth rate of 14.4±4.5 grams per day.

The growth rates of kittiwake chicks at Cape Thompson are compared to growth rates of chicks from Cape Lisburne in Table 36. Fifteen chicks at Cape Lisburne were weighed at intervals for at least ten days and nine chicks were weighed for at least 14 days. Growth rates during both intervals were essentially the same and were considerably greater than growth rates at Cape Thompson. The significance of the observed difference between the growth rates of chicks weighed for at least ten days at *Cape* Thompson and Cape Lisburne was tested using the Student's t test; the difference was found to be highly significant ($t=4.89$; $P \ll 0.001$).

Table 36. Growth rate comparisons of Black-legged Kittiwake chicks.

	Cape Thompson		Cape Lisburne	
	n	$\bar{x}$	n	$\bar{x}$
Chicks weighed at least ten days	9	14.2±3.4	15	20.1±2.5
Chicks weighed at least 14 days	5	14.4±4.5	9	19.3±2.5

c. Horned Puffins

A summary of the Horned Puffin uncompensated counts at Cape Thompson for 1960, 1976 and 1977 is presented in Table 37, and the 1977 plot counts are detailed in Tables 38-41.

Table 37. Horned Puffin census summary, Cape Thompson (scores are uncompensated).[1]

Year				*COLONY*			
	O[2]	1	2	3	4	5	Total
1960	32	128	243	71	168	163	805
1976	75	241	387	65	180	499	14473
1977	65	265	344	256	142		

[1]All 1960 totals for Colonies 1, 2, 3, and 5 listed in Tables 19, 20, 21 and 23 of our 1977 annual report are compensated scores. The 1960 total given in Table 22 for Colony 4 is uncompensated.

[2]'zero colony' is *located between Colonies 1 and 2.*

[3]*The Colony 1-5 (excluding Colony O) raw total of 1345 birds reported on page 31 of our 1977 Annual Report is in error. This total should read 1372.*

Table 38. Horned Puffin census, Colony 1; Cape Thompson, 1977.

17 August		
Plot	*Time*	*Observer E*
A	2055	32
B		
C		82
D		16
E		65
F		*13*
G		5
H		40
I	2155	12
	Total :	265

Table 39. Horned Puffin census, Colony 2; Cape Thompson, 1977.

14-15 July		
Plot	Time	Average counts of one-three observers
A_1	2200	4
A_2,B		0
C-F		65
G-J		86
K-N		29
O-R		44
S,T		28
u		15
V,W	0100	16
X,Y	2045	14
Z,AA		13
BB , CC		18
DD-FF		8
GG- I I	2300	4
		Total: 344

Table 40. Horned Puffin census, Colony 3; Cape Thompson, 1977.

16-17 August				
Plot	*Time*	Observer F	Observer E	$\bar{x}$
A	2225	6		6
B,C	2025		36	36
D	2230	0	0	0
E	2228	6	6	6
F	2223	1	1	1
G	2005	6	24	15
H	2212	16	17	17
I	1945	9	9	9
J	1916	25	25	25
K	1955	14	15	*15*
L	1948	8	8	*8*
M	1940	14	14	*14*
N	1945	14	14	*14*
o	2123	28	25	*27*
P	1930	13	14	*14*
Q	2105	24	26	*25*
R	2100	1	1	*1*
s	2055	23	23	*23*
Total		208	258	256

Table 41. Horned Puffin census, Colony 4; Cape Thompson, 1977.

3 August				
Plot	Time	Observer F	Observer G	$\bar{x}$
A-C	2250	36	39	38
D,E		9	9	9
F,G		3	3	3
H		3	3	3
I		4	4	4
J,L		10	10	10
K,O		13	13	13
M,N, P-R	2330	62	62	62
Total		140	143	142

Horned Puffins appear to have been present in about equal numbers in 1976 and 1977 at Cape Thompson. Although Colony 5 was not counted in 1977, numerous observations of Horned Puffins during the murre counts suggested that no major upward or downward change in the numbers had occurred since 1976. We believe that about 450-500 individuals inhabited this colony.

Swartz (1966) reported a compensated total of 1902 Horned Puffins at Cape Thompson in 1960. In 1976 the highest complete counts at Colonies 0, 1 and 4, combined with compensated totals for Colonies 2, 3 and 5 totaled 1918 birds. In 1977 we counted 1072 Horned Puffins at Colonies 0-4. Those data when combined with our estimate of Colony 5, suggest that little change occurred between 1976 and 1977. It also appears that little change has occurred between 1960 and recent years. These data suggest that at least 1500 Horned Puffins currently inhabit Cape Thompson and that an estimate of 1800-2000 individuals is not unreasonable.

Some changes in numbers at the individual colonies appear to have occurred, however, these differences between years may be largely artifacts of time, date, weather and observer bias.

A complete count of Horned Puffins at Cape Lisburne was not achieved in 1977. Storms prevented the completion of the census after 55 of the total 75 plots were counted. The results of counts are presented in Table 42. The total for the 55 plots was 1034 birds, a figure similar to the total of 1072 puffins obtained at five of six colonies at Cape Thompson in 1977. These data and other general observations throughout the summer lead us to believe that the total 1977 Cape Lisburne population was quite similar to that of Cape Thompson.

Horned Puffin laying dates were not obtained at Cape Thompson in 1977. Several eggs had been discovered by early August, although none had hatched by 23 August. Two nests occupied in 1976 at Colony 1 also were occupied in 1977. On 26 August a chick could be heard in one of these nests. We believe it was hatching or had just hatched. Based on a 40 day incubation period (see Swartz 1966) that egg was probably laid about 15-20 July. That date is very similar to the one laying observation we made in 1976 at the same location when an egg appeared in this crevice between 16-20 July. Swartz (1966) reported egg laying as early as about 25 June in 1960, and during the first week of July in 1961; he reported a replacement egg was laid between 23-26 July in 1961.

We have even less phonological information for Cape Lisburne. Homed Puffins did nest; we could see many of them entering and departing regularly from crevices and holes. We found only one nest, however. One egg was present in that nest as early as 9 July. We were unable to check this site for hatching later in the summer.

D. Glaucous Gulls

Early season information *on* Glaucous Gulls at Cape Thompson and Cape Lisburne was not obtained in 1977. Nests were not counted but some population size, phonological and reproductive success data are available *for comparisons between colonies and years.*

Nesting distribution at Cape Thompson was generally similar to both 1976 and 1959-1961. The most concentrated nesting occurred at Colonies 1 and 3. At least 32 pairs nested at Colony 1. Most of these

Table 42. Horned Puffin census; Cape Lisburne, 1977.

Plot	Date	Time	Total Birds
7	12 Aug	1800	2
8		1810	17
9		1820	6
10		1830	4
11		1850	6
12		1900	24
13		1910	8
14		1920	11
15	14 Aug	1900	18
16	27 Aug	1100	8
17			17
18			26
19			9
20			8
21			1
22			6
23			29
24			2
25			9
26			3
31			4
32			9
33			17
34			9
35			21
36			32
40			7
41			4
42			6
43			13
44			9
45			0
46			3
47			13
48			12
49			2
50			21
51			18
52	16 Aug	2030	45
53		2020	6
54		2010	13
55		19.50	22
56		1935	26
57		1920	38
58		1910	46
59		1840	73
60		1930	22

Plot	*Date*	*Time*	*Total Birds*
61		1915	96
62		1900	38
63		1830	58
64		1800	31
65		2115	37
66		2110	9
67		2105	46
69		2130	14
Total:			1034

pairs utilized the grassy slopes above the colony and were concentrated on narrow fingers which extended to the cliff edge.

Total numbers of gulls at Cape Thompson were not counted until 20-21 August. At this time all gulls between Ogotoruk Creek and Colony 5 were counted from the raft. Two hundred fifty adults, 164 juveniles (almost all fledged) and 26-27 subadults were counted. An additional 39-50 adults, 19-27 juveniles and 69-75 subadults were counted along nearby upcoast and downcoast beaches. Therefore, the minimum gull population in the vicinity of the Cape Thompson colonies totaled about 289-300 adults, 183-191 juveniles and 95-102 subadults. The number of adults present was quite similar to those figures obtained in 1960, 1961 and 1976, when 300, 300 and about 288 individuals respectively, were acounted for.

Fewer Glaucous Gulls appear to inhabit the Cape Lisburne vicinity. In 1976, during 26-29 August, we estimated that perhaps 100-200 individuals were present in the general area; no distinction was made between adults, subadults and fledged young in this rough estimate. In 1977, it was clear that only about 50 individuals at best occupied the Cape Lisburne colony. Of these, probably no more than 20 (ie., 10 pairs) nested. Only two actual nests were found and several other widely scattered pairs occupying the cliff-tops appeared to be regularly attending grassy, potential nesting sites. We believe the 1976 estimate was inflated by the presence of subadults (see below).

We have some *information* on the phenology of the *breeding activities* of *Glaucous* Gulls at Cape *Thompson and* Cape Lisburne in *1977.* At Cape *Thompson adults* were *observed* incubating on 8 June at Colony 1. Hatching was nearly complete by 6 July, our arrival date, and few chicks hatched after about 1 July. Two small downy chicks (about 70 g.) were located at Colony 1 on 7 July. These chicks were estimated to be 3-5 days old and probably hatched about 2-4 July. A few other relatively small chicks were located during the next week, however, most were relatively large. As early as 15 July seven well-feathered young were discovered at Colony 3.

Some juveniles were capable of flight during the third week of July . By the first week in August many young could fly, and by 15-20 August most of the chicks had fledged. Back-calculations, based on an average 50 day nestling period (range 42 to 57 days plus; see Swartz, 1966) suggest that most eggs probably hatched about 10-25 June. From all appearances, the progression of Glaucous Gull nesting at Cape Thompson in 1977 closely followed the schedule reported by Swartz (1966) for the years 1959-1961.

In 1976 fewer than half of the eggs had hatched by 28 June and the nesting schedule was about 10-15 days later than in 1959-1961 and 1977.

At Cape Lisburne, based on the two nests located, hatching occurred about 4 July in 1977; all chicks (five) observed on 14-15 July were estimated to be about 10 days old. In general, these two gull pairs were following a schedule that coincided with that of the latest 1977 Cape Thompson pairs. These pairs laid and hatched their eggs about 10-15 days behind the schedule most gulls followed at Cape Thompson in 1977, and in 1959-1961. The 1977 Cape Lisburne schedule appeared most similar to that observed at Cape Thompson in 1976..

Some measure of Glaucous Gull reproductive success was obtained in 1977. At Cape Thompson, the greatest numbers of adults counted at Colony 1, 63 and 64, were recorded on 13 July and 20 August, respectively. On 20 August 30 juveniles were counted among those gulls on their nesting area. These data suggest a minimum of 0.47 fledged young present per adult and a minimum of 0.97 fledged young per 'pair' if all adults were present (i.e. 31 pairs).

Similar data were obtained on gull nesting areas at Colonies 2, 3 and 4. The ratios of fledged young per adult and per 'pair' respectively were: Colony 2, 0.62 and 1.24 (42 adults, 26 juveniles); Colony 3, 0.52 and 1.03 (54 adults, 28 juveniles); Colony 4, 0.55 and 1.10 (20 adults, 20 juveniles). The average of all colonies was 0.53 fledged young per adult and 1.06 per 'pair' . Our counts of all gulls in the vicinity of Cape Thompson, including those listed above, yielded ratios of about 0.63 fledged young per adult or 1.26 per 'pair'. These data suggest that gulls at Cape Thompson probably produced about the same number of young as in 1976 when 21 nests had produced an average of 1.4 young each by 4 August.

At Cape Lisburne data from only two Glaucous Gull nests were obtained. Those two nests produced one 3-chick brood and one 2-chick brood. One small juvenile was found near death in the water below the nest that had produced 3 chicks. Later, both remaining fledged chicks from this nest were found shot. Both chicks successfully fledged at the second nest.

In 1976 subadult Glaucous Gulls did not associate with birds at the Cape Thompson breeding colonies until after July; the first subadults were not observed until 1 August. In 1977 subadult gulls again appeared in the vicinity of the colonies during the first few days of August. Subadults began mingling with the adults and fledglings and their numbers increased steadily throughout the next few weeks. By 20-21 August subadult birds accounted for about 6% of the total 440-441 gulls observed at the colonies on those dates. Of the remainder, 57% were adults and 37% were juveniles. An additional 127-152 gulls were located farther from the colonies along nearby upcoast and downcoast beaches. Thirty-one to thirty-three per cent of these birds were subadults, while 49-54% were adults and 15-18% were juveniles. Area-wide, of the total 567-593 gulls counted on 20-21 August, about 17% were subadults, 51% adults and 32% juveniles.

In 1976, 164 gulls in the immediate vicinity of the colonies were observed on 20 August. About 7% were subadults, 71% adults and 23% juveniles. The 1976 data were not obtained during colony-wide counts, and upcoast and downcoast beaches were not checked.

Subadult Glaucous Gulls also began appearing in the vicinity of Cape Lisburne during early August. On 2 August 12 subadults comprised about 13% of the total (89) counted away from the colony between Cape Lisburne and Thetis Creek. By 15 August subadults had become more numerous and were observed near the colony. No counts of the relative number of adults and subadults were made.

We have no evidence to suggest that depredation of gull nests by foxes occurred in 1977. Only one sighting of a Red Fox (Vulpes fulva) was obtained. This fox was observed hunting and traveling down Ogotoruk Creek on 7 July. No foxes were seen at Cape Lisburne.

E. Pelagic Cormorants

Pelagic Cormorants were found nesting only at Colonies 1 and 4 at Cape Thompson in 1977. More than twice as many nesting pairs utilized Colony 1 as had in 1976. Total pairs nesting at Colony 1 in 1977 also exceeded the total population recorded at Cape Thompson in 1976. Nevertheless, the total population size did not change much between the two years, and was similar to the number of pairs present in 1960 and 1961. The results of all years' counts are presented in Table 43.

We found 39 cormorant nests at Cape Lisburne in 1977. The nests were concentrated in two small areas; 27 were found on plots 47 and 48 and 12 were found on plots 54 and 55.

Table 43. Nests of Pelagic Cormorants at Cape Thompson.

	Colony					
Year	1	2	3	4	5	Total
1959	1	1	0	4	0	6
1960	3	18	0	1	1	23
1961	4	18	0	1	0	23
1976	7	2	0	5	0	14
1977	16	0	0	2	0	18

Cormorant productivity appeared good in 1977. At Cape Thompson data were obtained at only two nests, which averaged .%.5 large well-developed young on 23 August. At Cape Lisburne, average brood size obtained from 36 nests on 20 August was 2.06. That figure is higher than the brood size at Cape Thompson in 1976 (1.8 young/nest) and is comparable with data reported by Drury (1977) for cormorants nesting in Norton Sound.

Few data are available on the phenology of cormorants. At both Cape Thompson and Cape Lisburne this species appeared to follow a schedule approximate to that observed at Cape Thompson in 1976.

F. Tufted Puffins

Tufted Puffins were counted during all census activities and at other times as we traveled past the cliffs at Cape Thompson and Cape Lisburne. The numbers presented in Tables 44 and 45 are the highest counts we obtained in each of these locations during the summer.

Table 44. Populations of Tufted Puffins at Cape Thompson

	Colony					
Year	1	2	3	4	5	Total
1959	4	18	0	0	0	22
1960	20	12	0	0	4	36
1961	6	34	0	0	0	40
'1976	24	13	1	0	6	44
1977	13	9	4	0	3-4	29-30

'Table 45. Populations of Tufted Puffins at Cape Lisburne.

Year	Number Counted	Total
1976	(up to few 100's estimated)	few 100's
1977	11	11

The population size of Tufted Puffins at Cape Thompson has been historically small and variable. The apparent decrease in numbers between 1976 and 1977 does not appear significant when viewed in relation to 1959-1961 data.

The change in numbers of puffins seen at Cape Lisburne during the past two years was much greater. We did not make a formal count in 1976, however the birds were conspicuous and there was no doubt that they were much more numerous than at Cape Thompson. We estimated that at least 100 Tufted Puffins were present within the boundaries of the murre colony and many more occurred along the bluffs south of where murres were found. In 1977, the highest count we made totaled only eleven birds.

The significance of this decline is unknown. Since both colonies are in the northern-most nesting range of both puffin species, habitat utilization may vary considerably from year to year. In the case of Tufted Puffins, by far the least numerous of the two, some Cape Thompson data (see Table 37) are suggestive of this. Colony 1, because of its location, is the most often viewed. Tufted Puffins are generally conspicuous when present because of the broad flat rock faces and size of the cliff, and counts here are likely to be the most accurate. In five census years maximum counts have ranged from as low as two pairs (1959) to 'as high as 12 pairs (1976).

Nesting was not confirmed at either site in 1977. We suspect that attempts, at least, were made because we occasionally saw puffins entering or leaving burrows.

G. Guillemots

Guillemots also were counted during all census activities and at other times as we traveled past the cliffs at Cape Thompson and Cape Lisburne. The numbers presented in Tables 46 and 47 are the highest counts we obtained at each of these locations during the summer.

Table 46. Populations of Pigeon and Black Guillemots at Cape Thompson.

	Year				
Species	1959	1960	1961	1976	1977
Pigeon Guillemots	<10	4	14	4-6	2-3
Black Guillemots	<10	16	4	4-6	6-10

Table 47. Populations of Pigeon and Black Guillemots at Cape Lisburne.

	Year	
Species	1976[1]	1977
Pigeon Guillemots	0	1-2
Black Guillemots	<10	136-151[2]

[1]Data from 25-29 August only
[2]Includes one immature individual

The populations of both Pigeon and Black Guillemots frequenting the Cape Thompson cliffs are small (see Table 46). Swartz (1966) noted that Black Guillemots predominated in 1960, while, for unknown reasons, Pigeon Guillemots were the most numerous of the two species in 1961. In 1976 both species appeared to occur in about equal numbers, while in 1977 we found that Black Guillemots were slightly more numerous.

Pigeon Guillemots appear to occur even less frequently at Cape Lisburne (see Table 47). During our brief 25-29 August 1976 visit to this colony, this species was not observed; all birds encountered within positive identification range proved to be Black Guillemots. In 1977, only two observations of single Pigeon Guillemots were obtained at Cape Lisburne throughout the summer. These sightings occurred on widely separated dates.

The number of Black Guillemots encountered over the entire length of the Cape Lisburne colony in 1976 also was small. Fewer than 10 individuals were counted and it was our impression that there was little difference between the total population at this colony and Cape Thompson.

In 1977, however, Black Guillemots were relatively numerous when we arrived 6 July. During the remainder of July and the first week of August a minimum of between 136 and 151 individuals were found to be regularly present. Groups of 30-40 individuals commonly perched together in the evenings at or near the same boulder piles where most 1976 sightings had occurred.

After a severe storm on 8-9 August only a few pairs remained in the area. Those pairs might have been the ones that actually attempted to nest. Many of the birds we observed throughout July and early August had not appeared to be breeding. We do not know if a similar, larger 'early season' population attended the Cape Lisburne colony in 1976.

The generally small and variable number of both species which inhabit the Cape Thompson and Cape Lisburne colonies is probably related to the fact that the southeastern Chukchi Sea region encompasses the northernmost breeding range of the Pigeon Guillemot and the southern breeding range of the Black Guillemot. The availability of nesting habitat also probably influences guillemot numbers at Cape Thompson and Cape Lisburne. At both colonies preferred habitat appears limited. Talus fans are common, but only a few rubble piles comprised of larger boulders are present at Cape Thompson. Boulder piles, favored by both species, are somewhat larger and more numerous at Cape Lisburne, but even there they are concentrated in a few locations.

Some guillemot nesting data are available. Swartz (1966) located a total of four Pigeon Guillemot nests and one Black Guillemot nest at Cape Thompson in 1960-1961. All Pigeon Guillemot nests were situated in boulder piles. The Black Guillemot nest was located in a crevice several feet above a talus slide.

We were unable to locate nests of either species at Cape Thompson in 1976 and 1977, however, one pair of Black Guillemots frequented the 'best' boulder pile throughout the 1976 summer. At Cape Lisburne in 1976 a dead Black Guillemot chick was discovered at the edge of a large boulder pile. In 1977 at this same colony two Black Guillemot nests were located in similar boulder piles and other pairs were observed to frequent them.

Swartz (1966) reported the contents and fate of two guillemot nests at Cape Thompson. A Black Guillemot nest with two eggs was discovered on 3 July 1960. One egg was collected. Later, the remaining was found broken and the nest deserted. A Pigeon Guillemot nest was discovered on 29 July 1960. It contained two eggs. An adult was captured at the nest, identified and released. One egg also was collected. The nest and remaining egg were found abandoned later.

In 1977 a Black Guillemot nest containing two eggs was located on 12 July at Cape Lisburne. Our visit was short and the nest was not revisited until 25 July. A third visit on 5 August revealed that both eggs were broken and one contained a reasonably well-developed chick. A second nest entrance was located on our 25 July visit several meters from the first nest, in the same boulder pile. One adult was repeatedly observed carrying fish into it. We did not wish to disturb the nest; its contents and fate are unknown.

Although the data are limited, the above information suggests that both nesting guillemot species at Cape Thompson and Cape Lisburne are sensitive to human disturbance.

Some phonological data for guillemots are available. Swartz (1966) reported that Pigeon Guillemots were first observed at Cape Thompson on 12 June 1960. This species may have been present as early as 16 June in 1961, but positive identification was not made until 23 June. The last adults were observed near the colonies on 29 August 1960 and 28 August 1961.

Pigeon Guillemots were already present at Cape Thompson on our arrival on 20 June 1976. A few individuals were observed well into August 1976 and 1977. Swartz (1966) also reported that Black Guillemots were first observed at the colonies on 5 June 1960, and on 7 June 1961; birds were probably present through 28 August. This species also was present at Cape Thompson on 20 June 1976 and, were still present on 25 August 1976 and 26 August 1976.

Phonological data are not available for Pigeon Guillemots at Cape Lisburne in either 1976 or 1977. The downy Black Guillemot chick found in 1976 was discovered on 26 August. It probably was less than 10 days old. The two eggs which we discovered on 12 July 1977 at Cape Lisburne probably were recently laid. The size of the developing chick suggested that hatching would not have occurred much before 25 August, the date we found it broken open.

Several Black Guillemots were still present at this colony as late as about 1 September in both years.

Some Black Guillemot food habits data were obtained at Cape Lisburne in 1977. Many birds appeared to feed near the colony just offshore. Some individuals, however, were observed flying longer distances to the east and northeast. Fourteen observations of several birds carrying fish into boulder piles were obtained 22-25 July. In 12 cases these fish could be identified as small cod; in one case the fish was clearly an Arctic Cod and in another a Sand Launce was clearly visable. Because B. saida were numerous under the remaining ice floes near the colony, it is likely that most cod brought in were of that species. After 8-9 August, the primary food source of the remaining individuals was almost certainly A. hexapterus .

The numbers of guillemots at Cape Thompson and at Cape Lisburne are dwarfed by the populations of murres and kittiwakes. The role which guillemots play in the local marine ecosystem is also insignificant when compared to that of other species, especially murres.

Nevertheless, we believe that the presence of breeding guillemots of both species at Cape Thompson is particularly interesting. It provides an uncommon opportunity to study two geographically separated conspecifics at the interface of their distributions.

H. Raptor and Ravens

One pair of Gyrfalcons nested at Cape Thompson in 1977. This pair utilized the same site and nest ledge that they had occupied in 1976. Two chicks fledged from this nest about 20 July and continued to frequent the area throughout the remainder of our stay. One pair of Gyrfalcons also nested on a small seacliff east of Cape Lisburne near Corwin Creek. This pair produced two young and fledging probably occurred about 5-7 August.

Peregrine Falcons were not observed at Cape Thompson in 1976 or

1977. Both nesting sites utilized by this species during 1959-1961 were unoccupied in 1976. In 1977 one of these sites, a shallow scrape behind clumped grass on a small seaward ridge of Colony 3, was occupied by a nesting pair of Glaucous Gulls. Historical records of peregrine nesting at Cape Lisburne are not available. This species was not observed in the vicinity of this seabird colony during our brief visit there in late August 1976. In 1977 peregrine did not nest there, nor at various locales to the east and south. A single peregrine, however, was observed once near Cape Lisburne on 8 July. This bird appeared to be a female; it was never seen again.

Golden Eagles re-occupied the large nest situated at the north end of Colony 2 at Cape Thompson in 1977. This pair again successfully fledged one young. The chick was full grown and fully feathered by 23 August . It probably made its first flight within a few days of that time. Murres and Arctic Ground Squirrels (Citellus parryi) appear to constitute the bulk of the prey remains above, below and in the nest.

The same nest was present and Golden Eagles were occasionally seen near it in 1959-1961, but evidence of breeding could not be found (Swartz pers. comm.) . A second Golden Eagle nest was found about a kilometer inland from Colony 4; its current status is unknown.

Golden Eagles did not appear to breed at Cape Lisburne in either 1976 or 1977. One adult was occasionally observed above the cape in the vicinity of a nesting site that was active in the early 1970's (G. Netter pers. comm.).

Several subadult Golden Eagles were occasionally observed near the Cape Thompson and Cape Lisburne seabird colonies throughout the summer. On 21 August, a subadult female was observed atop Colony 3 plucking a freshly killed Thick-billed Murre.

Rough-legged Hawks (Buteo lagopus) are occasionally seen near the seabird colonies, however, this species has not nested there. At least a few nesting sites are situated several kilometers inland.

Ravens were common all summer at both Cape Thompson and Cape Lisburne. Numbers at Cape Thompson were similiar to those observed in 1976, and at least one pair nested there. At least one Raven pair also probably nested at Cape Lisburne. At both Cape Thompson and Cape Lisburne, Raven numbers increased during late July and August, as they had at Cape Thompson in 1976. Besides a few obvious family groups, occasional flocks of 10-15 individuals were observed 'working' the colonies in search of murre eggs.

I. Cape Lewis

We traveled by raft to Cape Lewis from Cape Lisburne on 27 July 1977. There we found large breeding populations of murres, kittiwakes, Horned Puffins and cormorants. In addition to those species Tufted Puffins, Black Guillemots and Glaucous Gulls were present and may have been nesting. Table 48 lists the results of our counts.

The average of two observers counts of murres was 19,130. We did not make compensation counts. If the overall percentage change between the raw mean score and the compensated mean score of Cape Lisburne murre census totals (28%) is applied to the raw census score from Cape Lewis, we

Table 48. Cape Lewis census, 27 July 1977.

Plot	Time	Murres			Black-legged Kittiwakes	Horned Puffins
		Observer E	Observer C	$\bar{x}$		
1	1830	295	240	268		
2	1830	2120	2080	2100	196	2
3	1850	660	530	595		2
4	1900	750	730	740		
5	1910	1025	1330	1178	217	12
6	1920	1635	1200	1418	147	11
7	1950	2270	2330	2300	312	28
8	2020	2785	2700	2743	253	20
9	2050	1890	2030	1960	270	18
10	2100	130	130	130	50	
11	2105	1055	970	1013	280	18
12	2115	1020	800	910	240	16
13	2130	2030	2020	2025	300	44
14	2140	2020	1480	1750	40	15
		19,685	18,570	19,130	2305	186

Cormorant nests: 28

Black Guillemots: 24

Tufted Puffins: 1

estimate that at least 26,500 murres could have utilized the cliffs. at this colony.

The raw score for kittiwakes is also probably lower than the total number of birds which actually utilized Cape Lewis. Many birds were seen flying in the vicinity of the cliffs and along the coast on either side of the colony during the time the counts were made.

The concentration of breeding cormorants at Cape Lewis relative to the size of the size of the colony was high. We found 28 nests, all of which appeared to be active.

The murres at Cape Lewis were feeding north of the colony. These movements were discussed earlier in this report. Similar observations of kittiwake flight directions were not made.

We determined the contents of most accessible kittiwake nests. The contents of those nests are listed in Table 49. The percentage of empty kittiwake nests at Cape Lewis (43%) was higher than the number of empty nests recorded at Cape Lisburne (28%) at about the same time.

The average clutch size determined from 23 active nests was 1.16. This was essentially the same as the kittiwake clutch size at Cape Lisburne.

Table 49. Black-legged Kittiwake nest and egg counts at Cape Lewis, 27 July 1977.

	Total Nests	Nest with 0 eggs	Nests with 1 egg	Nest with 2 eggs
No.	42	18	20	4
%	100	43	48	10

One adult Golden Eagle flushed from the pinnacles near the top of the cliffs. Several well-used perching places were evident, but we are not certain whether an active nest was present.

J. Other Areas Utilized by Seabirds

Seabirds were found at several headlands, bluffs and cliffs which occur both east and south of Cape Lisburne. Table 50 summarizes our observations, at those sites (see Figures 4 and 5).

Corwin Creek Bluff

The only seabirds apparently occupying this bluff were Pelagic Cormorants. No nests were found but the amount of white-wash on the rocks indicated that the birds perched there regularly.

Sapumik Ridge

A few Glaucous Gulls were found along the coast and could have nested there although no nests and only one fledged young were seen.

Table 50. Observations of seabirds st headlands, bluffs and cliffs east and south of Cape Lisburne, 1976 and 1977. Estimates are denoted by ( ) ; only th highest direct counts are listed.

Species	year	Corwin Creek Bluff[1]	Sapumik Ridge[2]	Niak Creek[3]	Bluffs south of Niak Creek[3]	Noyalik Peak[3]	Cape Dyer[4]	Kilikralik Point[5]
Murres	1976		a	a	a	(few 10's)	a	a
	1977	a	a	a	a	20	a	a
Black-legged Kittwakes	1976		a	a	a	a	a	a
	1977	a	a	a	a	a	a	a
Horned Puffins	1976		a	a	(several 10's)	(100±)	b	b
	1977	a	a	a	(few)	(30-40)	(16-30)	a
Glaucous Gulls	1976		present	?	?	12	present	b
	1977	a	(few 10's)	a	a	a	46-50	(several 10's)
Pelagic Cormorant	1976		a	?	a	(few)	50	(40-50)
	1977	33	a	6	s	9	26	(50±)
Tufted Puffins	1976		a	a	(several 10's)	(50±)	b	b
	1977	3	a	a	2	(12)	2-4	c
Black Guillemots	1976		a	a	a	a	b	b
	1977	a	9	a	14	a	a	c
Pigeon Guillemots	1976		a	a	a	a	b	b
	1977	a	a	a	a	a	a	c

[1] not visted by boat or aircraft in 1976
[2] data from 29 August 1976; 2 August 1977
[3] data from 28 August 1976; 13 and 27 July 1977
[4] data from 8 August 1976 (aerial estimate only); 27 July 1977
[5] data from 8 August 1976 (aerial estimate only); 20 July 1977 (aerial estimate only)

a - none observed from raft
b - none observed from airplane
c - none observed and presence doubtful

Niak Creek

Cormorants used a rock pinnacle just south of the creek mouth to perch on. One old nest was found, Gulls were flying in the area but we doubt they nested there.

Bluffs South of Niak Creek

Both Horned and Tufted Puffins were scattered along this section of coast, a length of about seven kilometers between Niak Creek and Noyalik Peak. We believe that both species probably nest in the steeper parts of the bluff.

Black Guillemots were seen on the water near the coast but we do not know if they nested in the area.

Noyalik Peak

In 1976 we christened this large, soft rock spire "Puffin High-rise". As many as 100 Horned Puffins and 50 Tufted Puffins were estimated to occupy this site and both species were seen entering and leaving the many burrows and crevices visible from shore. Consideralby fewer puffins were there in 1977, although most of those present probably nested.

Small numbers of murres and gulls also were found on the rocks. The gulls might have nested but we believe that the murres were loiterers.

Cormorants were present but not numerous and did not nest there in 1977, although two old nests could be seen.

Cape Dyer

Horned Puffins and gulls nested on Cape Dyer in small numbers. We found 13 active cormorant nestsin 1977; the estimate made from an airplane in 1976 of 50 individuals is probably too high.

Kilikralik Point

About 50 cormorants were estimated to have been on this point in 1976 and 1977. Whether or not cormorants nested there is not known, but the point was at least a popular perch for the birds.

A few adult gulls also were seen there and were possibly nesting, although we have no direct evidence.

K. Other observations

One of the highlights of the 1977 summer at both Cape Thompson and Cape Lisburne was the arrival of Sand Launce. The fish moved from north to south and appeared first at Cape Lisburne in late July.

On 25 July Black Guillemots were seen carrying Arctic Cod and a few Sand Launce to the cliffs at Cape Lisburne. Between 25 July and 30 July, kittiwakes were noted traveling more and more regularly in larger and larger numbers upcoast so on 1 August we collected kittiwakes returning from the east and examined their stomach contents. The majority of the birds had been feeding extensively on Sand Launce. We traveled upcoast as far as Thetis Creek, a distance of approximately 50 km on 2 August, and saw several feeding melees of kittiwakes near the Corwin Bluffs area. We were able to approach these groups closely enough to determine that the birds were feeding on Sand Launce.

A major summer storm hit the Cape Lisburne region about 8 August, creating high winds and high surf. Many Sand Launce were washed up on the beach at the Air Force site during that storm which began to subside on 10 August. On 9 August we observed unprecedented numbers of murres, kittiwakes and Glaucous Gulls feeding in large concentrations close to the colonies. Enormous feeding flocks of kittiwakes could be seen regularly in several locations around the colony. On the same date, we attempted to capture an apparently injured immature Glaucous Gull. When the bird was pursued, however, it regurgitated a large volume of Sand Launce and immediately became airborne.

Common Murres, which were collected on 10 August and which had been feeding to the northeast of the colonies were filled with Sand Launce. From then on through the remainder of our stay at Cape Lisburne, Sand Launce continued to be adundant in the region. The fish were the primary food of the majority, if not all of the kittiwakes, and also were heavily utilized by murres. Most other seabird species also probably utilized this resource above all others.

The stomach contents of both murres and kittiwakes collected at Cape Thompson indicated that small numbers of Sand Launce begin arriving within the feeding range of these birds about the same time as at Cape Lisburne. Large feeding aggregations of kittiwakes at Cape Thompson, however, were not observed until about 10-12 August. From then on, Sand Launce increased in importance, and by 17-23 August were being used almost exclusively by kittiwakes and heavily by murres.

The day of 23 August was a particularly calm bright day at Cape Thompson. At 1630 hours we observed from the top of Colony 4 a large dark mass, approximately 10 meters out from the surf. This mass proved to be a shoal of Sand Launce which was moving south. During the next hour we counted at least 15 other schools moving down the coast. The largest of the schools was about 5 x 10 meters in surface area and at least 1-2 meters in depth. The smallest measured about 2 x 2 meters in surface area and also was about 1-2 meters deep. Besides these large schools of fish, numerous small groups were also observed. Regardless of size, however, all schools were very dense.

Kittiwakes would regularly surface from a plunge with their mouths full of these fish; as many as 5 or 6 individual fish could be seen protruding from their bills. Glaucous Gulls had only to sit on the water and dip their heads under in order to obtain them. Murres 'ringed' the schools and dove, pausing underwater within a meter or so of the fish before dashing through them to surface several meters away. The action of the murres tended to fragment the schools but also drove the fish upward, keeping them within reach of the circling and plunging kittiwakes.

VII. and VIII. DISCUSSION AND CONCLUSIONS.

The numbers of birds we counted at Cape Thompson in 1976 and 1977 are almost certainly minimal estimates of the total populations which occupy the cliffs. Although we have evidence of rather well developed daily rhythms of cliff attendance by murres, the factors which we derived from the activity patterns to correct raw census scores probably do not account for all of the birds in the area. Furthermore, our experience has been that we tended to underestimate rather than overestimate numbers of birds at the cliffs. That tendency would also increase the size difference between the "real" and estimated totals.

The regularity and timing of daily attendance patterns at the cliffs was probably affected by several factors. These factors include variations in weather, changing daylength, food availability and the stage of the reproductive cycle. Those variables complicate the accuracy and precision of census counts.

Because compensation factors common to counts on different days in one season are difficult to derive, comparisons of counts made at different times and in different years should be made carefully.

The raw census total" obtained by Swartz in 1960 was 40% higher than our raw total for 1976 and 44% higher than our raw total for 1977. The differences between the compensated scores are greater; the 1960 compensated total was 54% higher than the compensated 1976 total and 60% higher than the compensated 1977 total. The relatively greater change observed between the compensated scores compared to the raw scores can be explained by differences between the way Swartz compensated his raw scores and the way we compensated ours.

Swartz determined daily activity patterns of murres in much the same way as we did, that is he counted the number of birds on small plots at intervals during the time that census counts were being made. Immediately after the census counts were complete, however, birds on the compensation plots were flushed and the eggs were counted. The relative number of breeding birds on the cliffs at different times were calculated by dividing the number of birds on compensation plots at time 't' by 2 x the number of eggs. From the bird and egg counts Swartz determined that, at peak times of attendance, there were 16% more birds on the plots that twice the number eggs. He suggested that those birds were attempting to breed but had lost eggs and not replaced them. The final correction factors used by Swartz to adjust raw scores took these additional birds into account. Raw scores were corrected not only for the daily activity patterns of the murres, but also were increased by 16% to correct for egg loss and replacement.

The method we used to compensate raw scores included daily variation in attendance only. Our attempts in 1976 to flush birds so that eggs could be counted were unsuccessful - enough birds always remained on the ledges to make visibility difficult and we could not be certain of how many eggs were present. Therefore, we did not correct our raw census scores for birds which might have been present but not nesting.

If the change in the murre population between 1960 and 1976-1977 is measured by the difference observed between the raw scores, the apparent decline is about 15% less than if differences between the compensated scores are used to measure the change. The magnitude of that difference (15%) is consistent with what one would predict, given knowledge of the two ways in which counts were compensated.

The differences discussed above, however, do not affect the suggestion which the data offer; that there probably were, in fact, fewer murres at Cape Thompson in 1976-1977 than there were in 1960 and 1961. Whether this change represents a gradual decline over the years or only a short-term fluctuation which might be related to yearly differences in certain environmental conditions is unknown.

With the exception of 1976, little variation has been observed in the schedule of murre nesting activities between years at Cape Thompson or between Cape Thompson and Cape Lisburne in 1977. The most reliable indicator of the breeding schedule is probably the dates when chicks begin to leave the cliffs. Because the vast majority of murres nest in places which are not visible, observations of 'first' eggs and 'first' chicks yield, at best, only a rough estimate of when eggs are first laid and first hatch. When chicks jump off the cliffs, however, they are very conspicuous and in general, the earliest chicks hatched are the earliest to jump.

The information obtained from food habits studies has shown that large yearly and seasonal differences exist in the prey utilized by both Common and Thick-billed Murres. Whether the changes are regular or random is still not clear.

Certain components of the total food resource appear to be 'more important' than others. For example, cod were taken much more frequently by thick-bills than were Capelin, and shrimp were taken more frequently than crabs. Both cod and shrimp rank high as principal components of this species' 'average' diet. The importance of these particular prey is not necessarily absolute, however. In 1977 cod were more important than sculpin in mid-July, but sculpin were more important than cod in mid-August. By late August, however, Sand Launce, which were taken in relatively low numbers through the middle of August, were more important than either cod or sculpin. The point is that, depending upon the season and/or the year, any of several species or groups of species should be considered critical to the murre populations at Cape Thompson and Cape Lisburne.

The relationship between the foraging flight patterns of murres at both colonies and the birds' food resources are not clear. We suppose that the birds feed in areas where they can optimise the energy return: effort ratio.

Alverson and Wilimovsky (1966) conducted fishery investigations in the waters around both Cape Lisburne and Cape Thompson. The areas in which they found the greatest concentrations of several fish and invertebrates coincided with areas we believe are important feeding grounds of murres.

Eight stations in the northern arc between west and east at Cape Lisburne were sampled during the last two weeks of August, 1959. The largest catches of Arctic Cod and Capelin were from two stations located generally northeast of the Cape. Those same stations also ranked high in relative numbers of decapods, particularly pandalid and crangonid shrimp.

In a large arc between Point Hope and Cape Krusenstern 63 stations were sampled. Decapods appeared to occur in greatest abundance in the deeper waters west and southwest of Cape Thompson (Sparks and Pereyra 1966). The highest catch of Capelin was at a station west of Kivalina (south-southwest of Cape Thompson) although Arctic Cod appeared to be most

numerous well off-shore and west of the Cape and Point Hope.

. The seasonal shifts in flight patterns observed in the murre populations may coincide with changes in food availability and 'hot spots'. Although certain areas may tend to be generally richer in prey, variations between years and seasons seem possible. That the changes in foraging areas occurredat about the same time at both colonies and approximately when murre chicks began to hatch could be significant. The paucity of information on the biological oceanography of the eastern Chukchi Sea, however, makes speculating on those relationships difficult.

As with the murres, we are not yet able to describe with certainty the relationship between the numbers of kittiwakes we have counted at Cape Thompson during the past two summers (about equal in 1976 and 1977) and the numbers which Swartz counted in 1960. The census methods were again somewhat different, Swartz counted nests and we counted birds.

We are certain, however, that recent productivity of kittiwakes at Cape Thompson, especially in 1976, has been much lower than it was in 1960. We would be surprised if the same proportion of birds even attempted to breed during the last two years as did during 1960, especially if the poor nesting success is related to a food shortage in the region of the colonies.

The average clutch size of kittiwakes at Cape Thompson has ranged from just over one in 1976 {for the few nests containing eggs) to as high as '1.92 in 1960. Likewise, the breeding success (chicks fledged/total eggs laid) of monitored pairs has varied widely between years; in 1976 the breeding success was essentially zero, but in 1977 and 1960 it was 65%.

The breeding success equality between 1977 and 1960 apparently occurred as a result of different factors. A greater percentage (25%) of the eggs laid in 1960 failed to hatch than in 1977, when only 9% failed to hat ch. However, 86% of the eggs that hatched resulted in fledged chicks in 1960 while only about 70% of the chicks which hatched could have fledged in 1977.

Even though the proportion of chicks fledged to eggs laid in both years was the same, the productivity of the population at Cape Thompson in 1960 was considerably higher than in 1977. The larger average clutch size in 1960 resulted in 1.22 chicks fledged per active nest compared to 0.77 chicks per active nest in 1977.

We have also observed differences in the productivity of kittiwakes at Cape Thompson and at Cape Lisburne in 1977. Although somewhat fewer kittiwakes may have attempted to breed at Cape Lisburne, a smaller number of those pairs which produced eggs failed than did at Cape Thompson. Perhaps the most striking difference between the colonies, however, was the remarkably rapid growth rates of chicks at Cape Lisburne compared to Cape Thompson.

The factors which influence elements of the breeding biology of kittiwakes are probably many and the interrelationships are certainly complex. Like most other birds which breed in higher latitudes, kittiwakes are undoubtedly under photoperiodic control for the initiation of the physiological changes associated with reproduction. The rate of development and the ultimate success of the breeding effort are probably attenuated by local environmental factors including weather, food availability and by the previous breeding experience of individuals and pairs. If trends

in seasonal utilization of different foods by both kittiwakes and murres have occurred regularly over the evolutionary history of these colonies, the breeding schedule may be timed, to some extent, to produce chicks coincident with seasonal food abundance.

Underlining many of the controlling factors is the common denominator 'energetic', and an intimate relationship between energetic and productivity certainly exists. For example, severe weather could be described as the proximate cause of a general breeding failure. Unless wind actually blew nests, eggs or chicks off of the rocks or unless surf and rain washed them away, the ultimate cause of the failure might be that weather interrupted the availability of energy to the adult birds. Even if only temporary, an interruption could easily result in an unsuccessful breeding attempt by pairs and by the population as a whole.

Similarly, variations in productivity between pairs of birds in a colony can often be attributed to age and experience differences of individuals. The point is that older birds might be able to secure energy more reliably than younger birds and, therefore, would have more to 'spend' on reproduction while still maintaining themselves.

We believe that at Cape Thompson, and at Cape Lisburne, the large differences we have seen in productivity, as well as in the timing of the breeding seasons and the growth rates of chicks, might be related to yearly, seasonal and regional differences in the amount of food available to the colony as a whole.

Swartz (1966) showed that the lowest average weight of male kittiwakes occurred upon their arrival on the breeding grounds. Throughout the summer males tended to gain weight and were heaviest upon their departure in October. The pattern in females was somewhat different than in males. Females gained weight between their arrival in May and late June, when they reached their maximum. The weight maximum coincided with the peak period of egg laying, after which time the weight of female kittiwakes tended to decrease through their departure in the fall.

We were able to show that the weights of Black-legged Kittiwakes are significantly correlated with levels of extractable fat in both males and females ($r = .674$, $p<.01$ for males; $r = .627$, $p<.01$ for females), and we believe that the observed weight increase of kittiwakes during the first part of the summer is related to increasing fat levels rather than to chance differences among the birds which were collected.

On 13 July 1977, male and female kittiwakes at Cape Thompson both had higher average weights than did male and female kittiwakes at Cape Lisburne on the same date. Nine males at Cape Thompson averaged 469±28 g and seven males at Cape Lisburne averaged 455±29g. Seven females at Cape Thompson and nine females at Cape Lisburne had average weights of 440±42 g and 411±26 g, respectively. The differences were not statistically significant; however, when the weight differences, especially between females, are viewed in terms of the timing of egg laying, they might have biological significance.

The phenology of breeding activities in 1960 was perhaps a little earlier than in 1977 and was certainly no later. During the interval 1-15 July, Swartz collected eleven male and ten female kittiwakes. The males weighed an average of 486.628.2 g and the females weighed an average of 449.929.7 g. Both of these averages are higher than those obtained on similar dates in 1977 at either Cape Thompson or Cape Lisburne.

In 1976 we collected seven males and four females between 1-14 July, the weights of which averaged 452±32 and 394±55, respectively. Those averages are considerably lower than either 1960 or 1977 and the breeding schedule in 1976 was much later than in either of the other two years.

The laying dates of kittiwakes at both colonies for all years appear to be related to the average weights of female kittiwakes collected during the interval 1-15 July of the respective year. The heavier the average weight was, the earlier the date of laying. These data, together with the correlation between body weight and fat levels, suggest that certain energy requirements may have to be met by the female birds before they will. lay eggs.

If an energy threshold must be reached to initiate laying, the magnitude of energy reserves above that threshold could contribute to the number of eggs laid. It may be significant therefore, that clutch sizes averaged largest at Cape Thompson in 1960 and were progressively smaller at Cape Thompson in 1977, Cape Lisburne in 1977 and Cape Thompson in 1976.

Unfortunately, we do not have early season food habits information for kittiwakes at either colony. We do know that kittiwakes were feeding heavily on cod at both sites during the period when egg-laying occurred. By the time eggs were hatching at Cape Thompson, however, we believe that cod were much less available and Sand Launce had not yet arrived. At Cape Lisburne cod had also declined, at least in utilization, by the time eggs hatched, however, Sand Launce had arrived there in large numbers and were being fed on heavily by adults and were being fed almost elusively to chicks. The abundance of Sand Launce, coincident with the hatch of chicks at Cape Lisburne, probably explains why growth rates and fledging success were higher at Cape Lisburne than at Cape Thompson.

As with murres, we are reluctant to designate particular prey species as critical to kittiwakes. Sand Launce are undoubtedly important, at least during late summer when energy requirements are particularly high because of rapidly growing chicks. We do not know whether Sand Launce have occurred in large numbers near Cape Thompson and Cape Lisburne during early summer in other years, or whether the late arrival of these fish is characteristic. If they are not generally abundant until August then they are no more important to the kittiwake population than are those prey upon which the bird feed during May, June and July (for example cod). Both Arctic and Saffron Cod were taken frequently by kittiwakes prior to the arrival of Sand Launce, and the relative abundance of cod may well have determined the relative importance of Sand Launce. That is, Sand Launce were important in 1977 because there were chicks to feed; in 1976 Sand Launce in August would have been of much less significance since very few eggs were being laid.

Our studies and the work done by Swartz during 1959-1961 are beginning to demonstrate the magnitude of "natural" fluctuations in the breeding success of kittiwakes on a colony wide basis. We believe that those fluctuations are of particular significance with regard to oil development in the Hope Basin.

We do not know the rate at which productivity will recover following a year like 1976. Unless the kittiwake populations at Cape Thompson and Cape Lisburne rely on immigration of birds from colonies farther south, productivity can not remain low without jeopardizing the health of those populations. If food web organisms were adversely

affected by oil related activities, that impact could compound the effects of a "natural" prey decline and prolong the recovery of kittiwake nesting success.

With the possible exception of puffin numbers, little overall change in the biology of gulls, guillemots, cormorants and puffins has been observed at our study sites. All of those populations are small compared to murres and kittiwakes, and except for gulls, probably contribute little to the ecology of the area. Glaucous Gulls undoubtedly affect the production of murre chicks, the extent of which is difficult to assess. The availability of habitat and food for murres, however, is probably of much greater significance to the population than *is* gull predation.

1X. SUMMARY OF 4TH QUARTER OPERATIONS

A. Ship or laboratory or field activities

1. No field work was conducted during the 4th quarter.

2. The scientific party for the 4th quarter included: Alan M. Springer, PI; David G. Roseneau, PI; Martha I. Johnson, Research Assistant; and Peter J. Bente, Biologist.

3* Sorting of voucher specimens from stomach food samples was completed by Dr. Peter Craig, Fisheries Biologist (LGL) and Dr. C. Low, Nanaimo, British Columbia.

4. No samples were taken during the 4th quarter.

5. No field data were collected during the 4th quarter. Several parasite specimens collected in 1977 and sent to Eric Hoberg and Dr. Robert Rausch, University of Saskatchewan, have been identified. A brief summary of these data will be included in the final report.

6. Data submissions schedule:

a. We expect to begin submitting 1976 and 1977 data according to the new 'A35 Bird Colony' formats and the new USFWS food habits and specimen records after the completion of the upcoming summer field season. Data collected in 1978 will be entered on format field forms and also will be submitted at that time.

b. Discussions about the 'workability' of the old "035 Bird Colony Format" were held with Arctic Project Office personnel. The '035' format and a new format, proposed by the U."S. Fish and Wildlife Service, were reviewed and comments were submitted to Marcy Butcher, Juneau, and Mike Crane, AEIDC, Anchorage. D. G. Roseneau attended a meeting of other seabird colony PI's, NOAA, Arctic Project Office, BLM and USFWS personnel at the NOAA offices in Boulder, Colorado, 20-21 March 1978 where both formats were reviewed by the group. A colony census record was submitted for inclusion in any new format scheme. Data submissions had posed a problem since the "035" format continued to present difficulties in data entry. A new bird colony format', a result of the 20-21 March 1978 meeting in Boulder, will now allow us to prepare field forms and enter R.U. 460 colony census data.

B. Problems encountered/recommended changes

No major logistic or scientific problems were encountered. Data entry and submission had posed a problem (see above). This problem appears to be resolved.

C. Estimate of funds expended

	Project Initiation to 31 March 1977	31 March 1977-31 March 1978	Total
Cape Thompson			
Personnel	$36,584.26	.$13,845.48	$50,429.74
Expenses	20,663.30	9,886.28	30,549.58
Total	$57,247.56	$23,731.76	$80,979.32
Cape Lisburne			
Personnel	$ 434.94	$ 7,081.44	$ 7,516.38
Expenses	0	6,272.81	6,272.81
Total	$ 434.94	$13,354.25	$13,789.19
Radio Telemetry Pilot Study			
Personnel	$ 0	$ 2,150.50	$ 2,150.50
Expenses	0	$ 2,477.29	$ 2,477.29
Total	$ 0	$ 4,627.79	$ 4,627.79

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The field party this summer consisted of Dr. Ed Murphy, Martha Johnson, Sony Power, John Stern, Gretch Murphy and Peter Bente. Without their effort the majority of data presented in this report would not have been collected.

The identification of foods eaten by murres and kittiwakes were conducted by Dr. Peter Craig (currently with LGL, Ltd.) and Dr. C. Low of Namaimo, Britich Columbia.

Major Joseph Zadareky, Site Commander, 711th Aircraft Control and Warning Squardron (AAC), Cape Lisburne, and his personnel were especially cooperative and hospitable during our stay. Mr. Gene Horsewood, RCA manager and many of his staff helped make our stay comfortable and productive by providing us dining privileges and materials and assistance in maintaining some of our equipment.

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